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GEORGE LIVINGSTON, Acting Chief

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CONSTRUCTION AND FIRE PROTECTION OF COTTON WAREHOUSES.[1]

By J. M. Workman.

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PRIMARY FACTORS IN WAREHOUSE DESIGN.

The construction and fire protection of warehouses for cotton has suffered much from the apparent simplicity of the subject. The majority of cotton warehouses do not combine the essentials for real economy of construction and fire protection with advantageous insurance rates largely because of inefficient planning. The design and construction of the cotton warehouse should be handled by a competent engineer having a thorough understanding of construction, fire protection, insurance requirements and rates, together with some knowledge of warehouse management.

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[1] Definite suggestions in regard to construction of buildings and fire protection based on desirable principles and practice are presented in this bulletin. Very detailed information, of interest chiefly to the designer of warehouses, is printed in small type as footnotes.

These recommendations as to construction are in general harmony with the Building Code recommended by the National Board of Fire Underwriters. Acknowledgment is made of valuable assistance rendered by Prof. Ira H. Woolson, in the preparation of this discussion.

The success of the cotton warehousing business is strongly influenced by the elements of cost of construction on the one hand, and insurance rates on the other, for these two factors determine very largely the returns on the investment. Primary factors determining warehouse design are the character and volume of the business contemplated, the site for the plant, and the possible arrangement of the buildings.

Certain conditions vitally affect the adoption of both site and arrangement of the plant. Some of these conditions are whether cotton is handled primarily for producers or dealers, with the consequent influence on " turn overs " and " peak loads," whether it is deposited and withdrawn in large or small lots, is generally for shipment to local or to distant points, is stored flat or compressed, is subject to favorable shipping rates. It is apparent that warehouses for local storage, for use as a concentration or compress point, for an export plant, or for a cotton mill warehouse, will present separate problems both from the standpoint of the actual plant and of the handling system and storage methods employed. The solution of these problems is a matter of managerial policy and does not lie within the scope of this discussion.[1]

The site for the plant should be considered with reference to transportation facilities, area available, topography of the ground, character of the soil, and the water supply which is available or can be provided. Transportation connections by both water and rail are desirable, while for the plant handling cotton in large quantities for distant delivery, as at concentration points, such connections may be indispensable. The area available may limit the distribution of the buildings and consequently the design. The toporgaphy of the ground influences both arrangement and design, while the character of the soil sometimes affects the cost of construction with a resulting influence on economy of design. As a rule, no warehouse should be built unless it can be provided with a sufficient water supply for reasonable fire service.

The layout of the plant, or the arrangement of the buildings, should be influenced primarily by the elements of fire hazard, convenience for handling cotton, and the design of the building desired considered with the economical type of construction. Protection against fire exposure demands isolation of buildings and restriction in size of units. At the same time, the arrangement should be such as affords the greatest economy in handling the cotton, which preferably should be moved into the warehouse from one side and turned out from the opposite side. The design of buildings with reference to size and proportion of compartments, story height, and number of stories should be based upon all of the foregoing facts considered in conjunction with the relative cost of various types of construction and the resulting rate of insurance.

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[1] Newton, Roy L. and Workman, J. M. Cotton Warehousing—Benefits of an Adequate System. In Yearbook of the U. S. Department of Agriculture, 1918.

SOME TYPICAL WAREHOUSE PLANTS.

The selection of the type of construction and design of the buildings used is a matter for the decision of the management, as it is not possible to state that any one type of construction and design is best regardless of the conditions to be met.

A single-story warehouse of semi-slow-burning construction—that is having a heavy timber roof, light frame exterior walls, and brick division fire walls—is shown in Plate I. This plant is well removed from exterior fire hazards so that the construction used is safe and economical. It is used for storing cotton for large producers and the uncompressed bales are tiered five high during the time deposits are heaviest. A story height of 16 feet is used and the building has five compartments with a combined capacity of 5,000 bales of uncompressed cotton.

A large export plant, also of semi-slow-burning construction, is shown in Plate II. Here the buildings are 100 feet wide and are cut into compartments by division fire walls spaced at intervals of 50, 75 or 100 feet. The buildings are arranged in pairs with receiving or delivery courts 100 feet wide between, to provide the necessary isolation and give space for operations of firemen if need arise. Plate III, figure 1 shows a court used for receiving cotton from cars; there is also shown the depressed tracks and the hose houses. In alternate courts the central area is paved and the tracks are omitted. Here the cotton leaving the warehouse for the compress or for shipment by water is handled on low flat trucks drawn by electric storage battery tractors.

In this plant reliance for protection in case of fire is placed in the system of yard hydrants, a complete automatic sprinkler system with ample sources of water supply, and an adequate watchman service.

Plants in which the buildings present exposures to each other, or plants subjected to dangerous exterior exposures (including a passing locomotive) should not depend entirely on fire-protective equipment, but should offer in themselves a strong resistance to fire. It must be remembered that congested handling of cotton in courts between warehouses causes such buildings to present a hazard to each other that may be very serious. An inexpensive method of securing protection from such exposures is to use masonry for the exposed walls and frame construction for the walls not exposed. In the case of a number of parallel buildings with courts between only one exterior side wall of each entire building may be masonry. Such an arrangement is good but is not nearly so satisfactory as when all walls are masonry.

Slow-burning construction is illustrated by the photograph of a warehouse of three-story design in Plate III, figure 2. This building has floors and roof of timbers and heavy planking, exterior and division walls of brick, with tin-clad fire doors throughout. The platform is of reinforced concrete which requires practically no repairs and does not communicate fire. In this building the story height is only 8½ feet and cotton is stored one bale high on end. Such buildings should not exceed three stories in height unless there are floors of reinforced concrete to serve as fire breaks. The type of exterior door used in this building is shown by Plate XIII, figure 2.

A similar building, well suited to conditions which demand concentration or where the area is limited, is shown in Plate IV, figure 1. For buildings of this design it is best that all floors be fire-resistive. The fire-resistive floor has the advantage of limiting the amount of cotton subject to a single fire and, what is more important, it serves as a tie to the walls and prevents their subjection to such severe and prolonged heat as to cause their failure from expansion. For such buildings the automatic sprinkler equipment is practically essential, while the installation of stand-pipes with hose equipment on each platform is of great importance. A view of such a standpipe and hose equipment is shown in Plate XXXII. It usually is not necessary to have platforms on both sides of the building, but if platforms are omitted on one side, doors of sufficient number and size should be provided on that side to permit of cotton being thrown out and, more important, to admit of ready access by firemen. These features of construction are illustrated by Plate IV, figure 2. In this view the minimum number of doors advisable is shown. If any floors in the building are fire resistive, or if the exterior exposure is hazardous, doors should be covered with tin as described for fire doors under "Fire-resistive construction," or should be otherwise equivalent to fire doors. The iron ladder gives ready access to the doors.

Fire-resistive construction for the warehouse does not involve any radical departure in design from the slow-burning construction described. The difference is that all floors and roof are of fire-resistive material, such as reinforced concrete, and that openings are fully protected as required by their location and exposure. The construction of the floors and other features are discussed under "Fire-resistive construction." An interior view of such a building showing the arrangement of the automatic sprinkler heads and method of storing is shown in Plate XVI, figure 1, and the exterior of such a building is shown in Plate XVII, figure 1.

COTTON HANDLING EQUIPMENT.

Inasmuch as the design of building adopted is related to the handling equipment employed, this equipment should be provided for at the time of construction.

For the majority of warehouses the two-wheel truck is in general use. These may be had constructed entirely of steel.

Large plants are using the electric storage battery truck or tractor and trailers to a considerable extent. The latter arrangement is quite satisfactory for cotton handling. A photograph of such a tractor and a train of cars loaded with cotton is shown in Plate V. The low trailer cars are easily loaded without lifting the cotton. They are arranged to follow the tractor accurately, so that a train of several cars is carried readily through doors and around corners. These tractors may be operated inside the storage compartment without danger of fire. There are several makes of tractors on the market, some being driven and steered by all four wheels, others being driven by two wheels and steered by two, while still another type has but three wheels, using two as drivers and one as a steering wheel. Batteries are charged at night and operated all day.

Several large warehouses use an overhead trolley system such as is shown in Plate VI. While this system is developed well for these particular plants, it is not recommended for the average warehouse.

In the warehouse of several stories elevating equipment usually is needed in addition to trucks. Two-story warehouses occasionally can be arranged so that cotton is received on the level of the upper floor, 4 feet above the driveway or railway siding. The bales may then be trucked down an inclined platform or sent down a sliding chute, such as is shown at about the center of the platform of the warehouse illustrated in Plate III, figure 2. In such case it is necessary to provide a railway siding depressed sufficiently to bring the car floor to the platform level. Unfortunately, such arrangements seldom can be made economically. There are but few conditions which justify the labor of trucking up an incline. so that elevating equipment usually must be provided.

A development of the incline for elevating cotton placed on the two-wheel truck is shown in Plates VII, figure 1, and Plate VIII. This consists of an incline, preferably of reinforced concrete, containing a slot in which travels an endless sprocket chain having bracket or hook links at intervals. These hooks engage the axle of the truck and pull it up the incline, the truckman holding the handles as shown. The endless chain is driven by an electric motor or other power. The truck is generally brought down an incline which is similar except that the sprocket chain is omitted and the slope is less steep.

The electric hoist is valuable in a warehouse in which cotton is handled rapidly. An illustration of this equipment is shown in Plate VII, figure 2. The machinery is protected in the little house shown on the steel frame. Two motors supply both vertical and lateral movement to the steel hooks carrying the bale. This equipment can be housed under the warehouse roof and controlled from any floor by a cable at the doors. This hoist will handle readily 100 bales an hour from the first to the third or fourth floor, a little more time being required to deliver to higher floors. However, several men are required for the operation of the hoist, as there must be one man to operate the machine, one on the lower floor to hook the bale, and one on the upper floor to release the bale, besides those assigned to trucking the cotton to and from the hoist. The hoisting apparatus may be used also for lowering cotton, although better and more economical results are secured from the use of a bale chute.

The ordinary spiral package chute of sufficient size supplies the best means for lowering cotton. Views of this form of chute are shown in Plate IX, figures 1 and 2. The installation shown is arranged so that the bales are delivered to the bottom floor already headed up and ready for the truck. A straight chute can be constructed of skids, 3 inches wide, and shod with heavy strap iron. The chute may pass through a number of floors and, by the use of trap doors, bales may be delivered from any floor to any other floor below. A bale chute and an electric hoist are shown in the warehouse in Plate III, figure 2.

Where the conditions do not demand rapid elevation of the cotton or where available labor is limited the regular platform elevator is the best hoisting equipment. Such elevators may be operated by a belted mechanical connection, by electric motor, or by direct steam connection. The elevator also may be used for transfer of electric trucks or loaded trailers from one level to another. The arrangement of the building for an elevator used for cotton bales is shown in Plate X. A somewhat different arrangement is desirable if electric trailers are to be handled on the elevator.

In addition to these forms of handling equipment the slatted belt conveyor arranged on an incline and with spiked slats for engaging the bales of cotton is used to some extent.

For piling cotton the machine in most general use is a small portable elevator such as shown in Plate XI. The movable platform is equipped with a series of rollers so that the bale, when elevated to the top of the pile, may be pulled off easily. Another good type of this machine is arranged to revolve upon the castored truck base, which gives great convenience in moving and setting. The machines are constructed for operation by hand and by electricity. The hand machines are necessarily rather slow in operation when elevating a bale of cotton, but the electric machines make possible very rapid piling. When they are equipped with a properly enclosed motor, the machine affords practically no fire hazard, provided the wiring and all connections are properly designed and installed. The cable extending to the machine should be inclosed in a flexible metal conduit and all socket connections should be located on the ceiling. By using a cable with a length equal to the combined height of the story and of the machine and by connecting the cable to the top of the elevator it is possible to move the machine within a circle of considerable area without the cable coming in contact with the floor. In cases where the cable is allowed to lie on the floor and is not inclosed there is introduced a serious fire hazard because of the probable damage to the cable from trucks passing over it.

Scales in general use for weighing cotton are the ordinary beam scale, the portable platform beam scale, and the dial scale, which may be stationary or arranged on castors so that it can be moved from one to another of a series of very shallow pits. This movable dial scale is well adapted to weighing the bale of cotton while on the truck for the platform is large and a "tare beam" is provided for deducting automatically the weight of the truck. A view of such a scale in use is shown in Plate XII. Since this method of weighing requires that trucks be of a uniform weight, those made of steel are particularly desirable. The illustration shows portable inclines on each side of the scale. This arrangement is excellent where the shallow pits can not be provided readily. Such scales are coming into more general use and are beginning to displace the beam scale, which for a long time has been considered standard equipment for the cotton warehouse.

THE WAREHOUSE PLANT AND BUILDINGS.

Local conditions influence the layout of the warehouse to such an extent that the arrangement of buildings should be decided upon after consideration of these factors and with the approval of the insurance rating bureau having supervision of the particular territory involved.[1]

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[1] Nixon, Robert L. Cotton Warehouse Construction. U. S. Department of Agriculture, Bulletin 277, 1915.

Fundamental requirements for the arrangements of buildings not only demand that they be isolated as much as possible from adjacent property hazards, but that the several buildings should be arranged in such manner as to minimize the exposure, or fire hazard, that they present to each other. This is so important that it should be the first consideration in the design of the plant. Among exterior fire hazards a passing locomotive should not be overlooked.

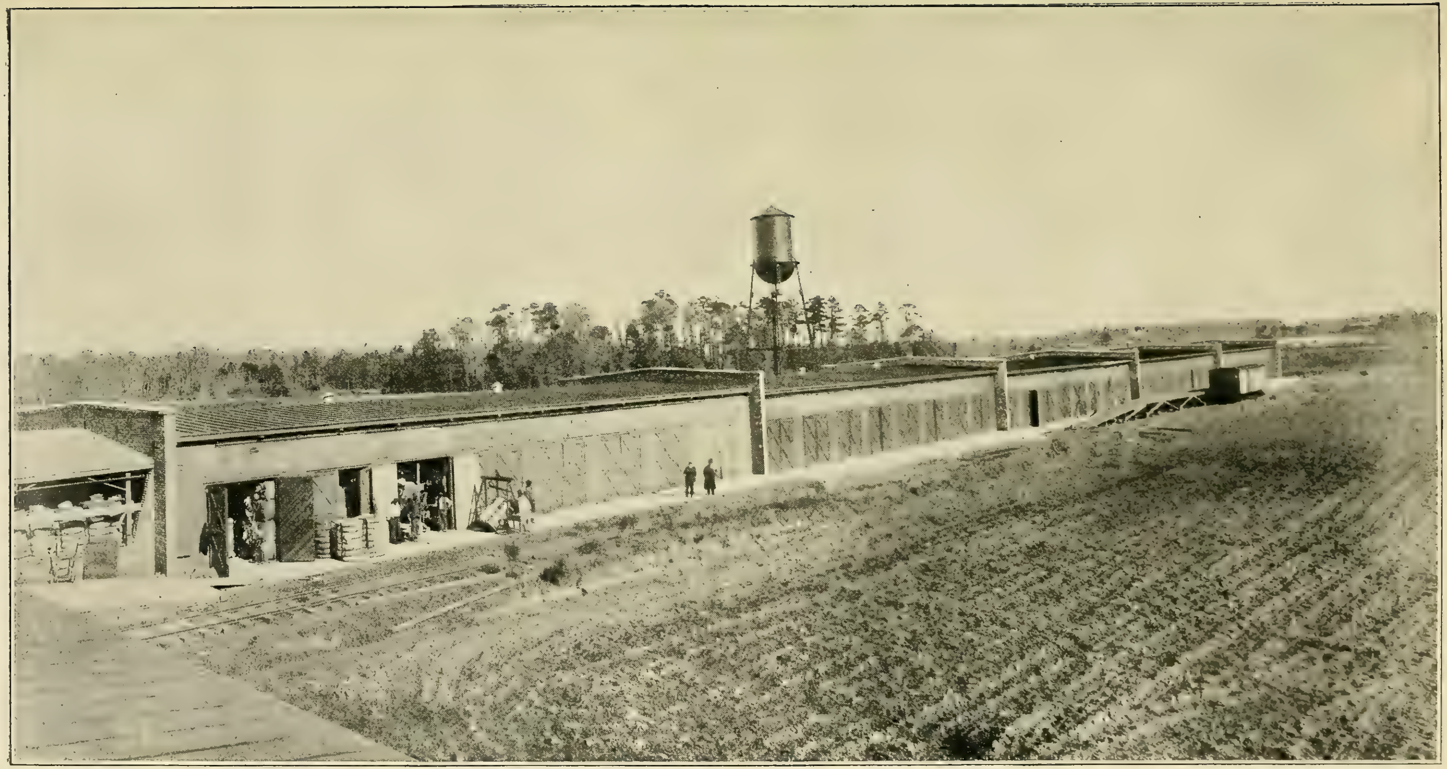
The buildings necessary for a complete warehouse plant vary according to the nature of the business conducted. In addition to the warehouse storage compartments there may be the compress compartment, sheds for receiving and delivering cotton, boiler house, pump house, hose or hydrant houses, office and classing rooms (which may provide a file room for cotton samples), and a watchman's room. Each of these buildings presents definite requirements for construction and fire protection.

The design of the warehouse buildings should be selected with a view to the cost of construction, maintenance and operation on the one hand, and resulting fire hazard and insurance rates on the other. The most important item from both standpoints is the size and proportions of the compartments. After the capacity of the compartment is determined, its proportions must be considered in adopting a particular type of construction. The design of the building as regards the number of stories is usually determined by local conditions, but, all things considered, the single story warehouse is to be preferred in the majority of cases, if cotton can be piled with reasonable convenience. If cotton is not piled, the building of several stories is more economical and convenient.

The warehouse building should be divided into compartments in order to reduce as far as is economically practical the amount of cotton which may be subjected to a single fire. A compartment may be considered as that portion of the building which is cut off from all other parts of the building by fire-resistive division walls, or such walls and fire-resistive floors so combined that a fire will not be communicated readily from one of these sections to another. This reduction of single areas and protection of each against the other is a principle of the greatest importance in cotton warehousing.

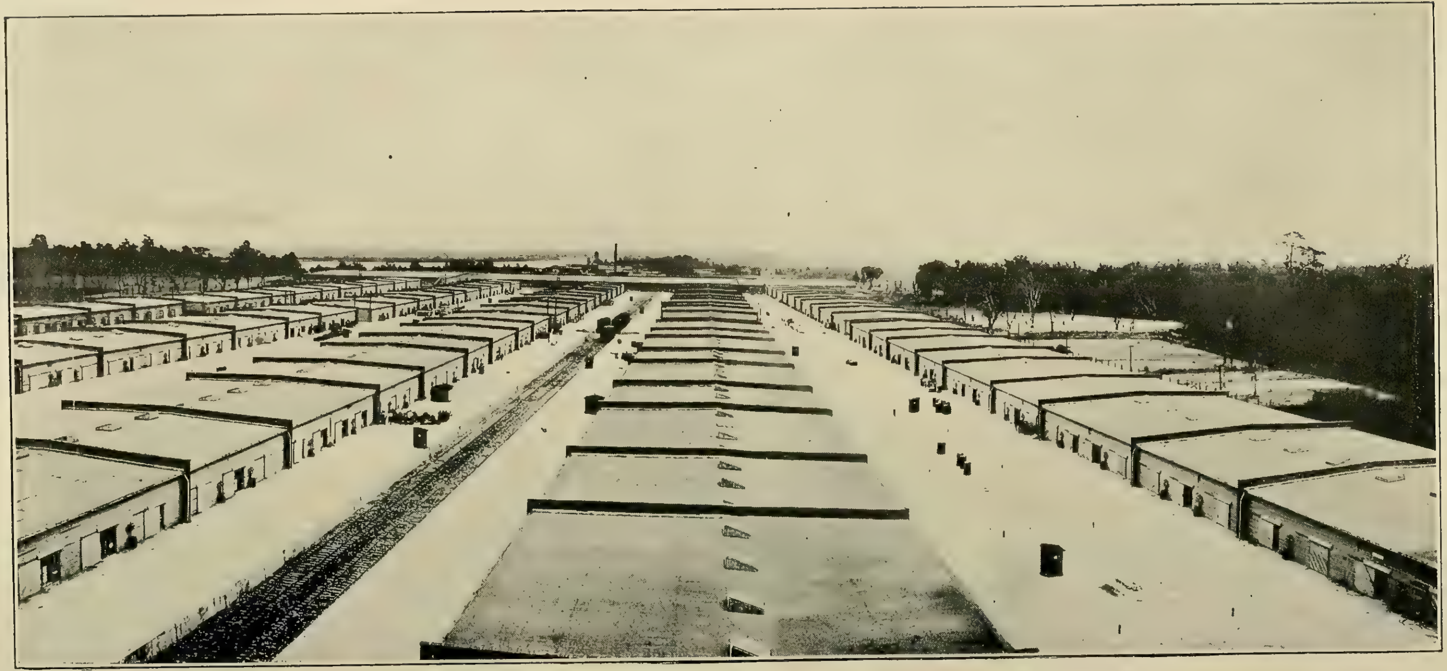
THE COMPARTMENT.

The size of the compartment should be such as to limit the cotton which may be stored therein to an amount of reasonable value. It usually is conceded as desirable that the size of the compartment should not permit the storage of more than 600 bales of cotton, while in few cases should the number of bales exceed 1,000. This view of the capacity of the storage compartment conforms to the usual in-



A SMALL TOWN WAREHOUSE OF 5,000 BALES CAPACITY.

The building is of the semi-slow-burning type of construction, the exterior walls entirely of doors or of doors and light framing weatherboarded.



A CONCENTRATION AND EXPORT PLANT OF SEMI-SLOW-BURNING CONSTRUCTION.

The wide courts are for receiving from cars and for delivery to the compress in the background. The hose houses are located between the buildings.

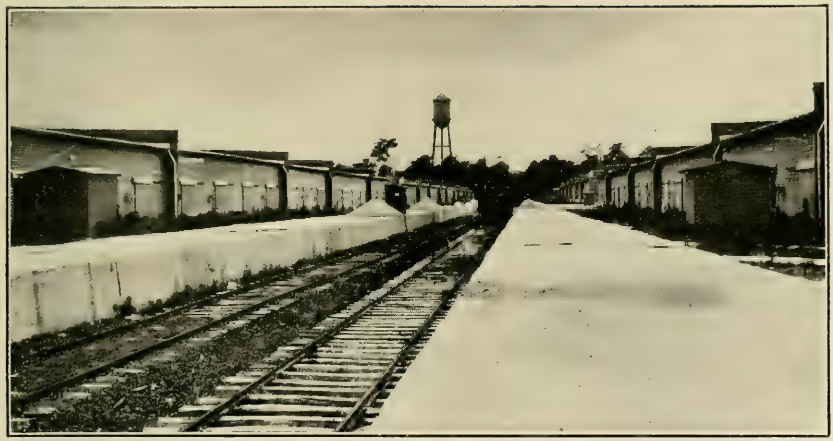


FIG. I.—VIEW OF RECEIVING COURT WITH DEPRESSED TRACK AND PAVED RUNWAYS.

Cotton is handled from the cars and into and out of the warehouse both by the ordinary two-wheel hand truck and by electric tractors.

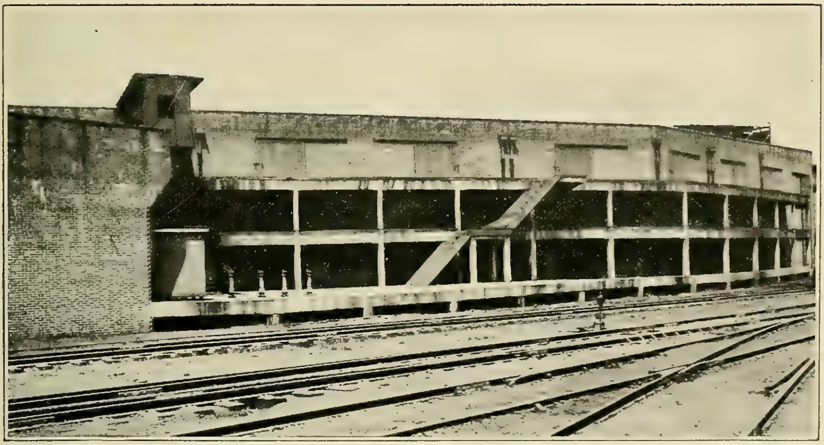


FIG. 2.—AN EXCELLENT WAREHOUSE OF SLOW-BURNING CONSTRUCTION WITH PLATFORM OF REINFORCED CONCRETE AND DOORS TIN COVERED.

Note the electric hoist at the left and bale chute and stair combined at the center.

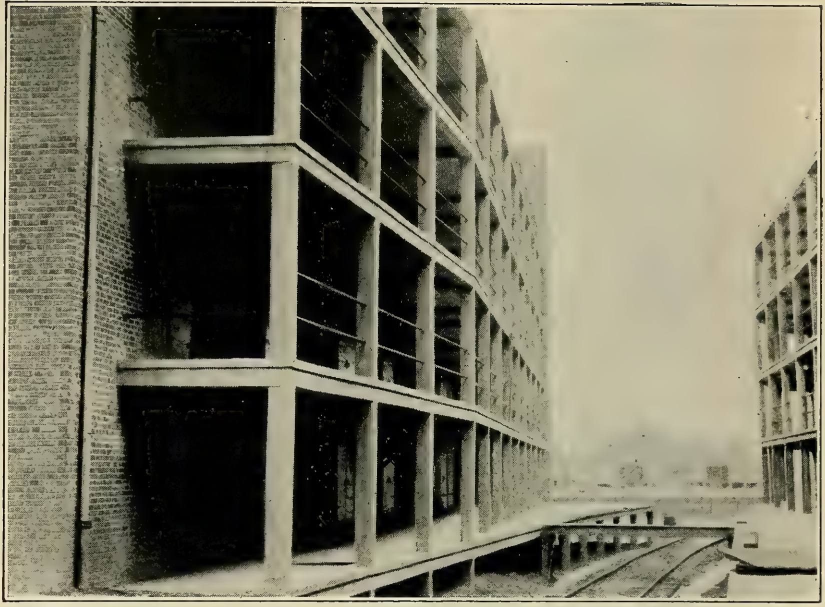


FIG. 1.—A WAREHOUSE OF FIRE-RESISTIVE OR SLOW-BURNING CONSTRUCTION WITH PLATFORMS.

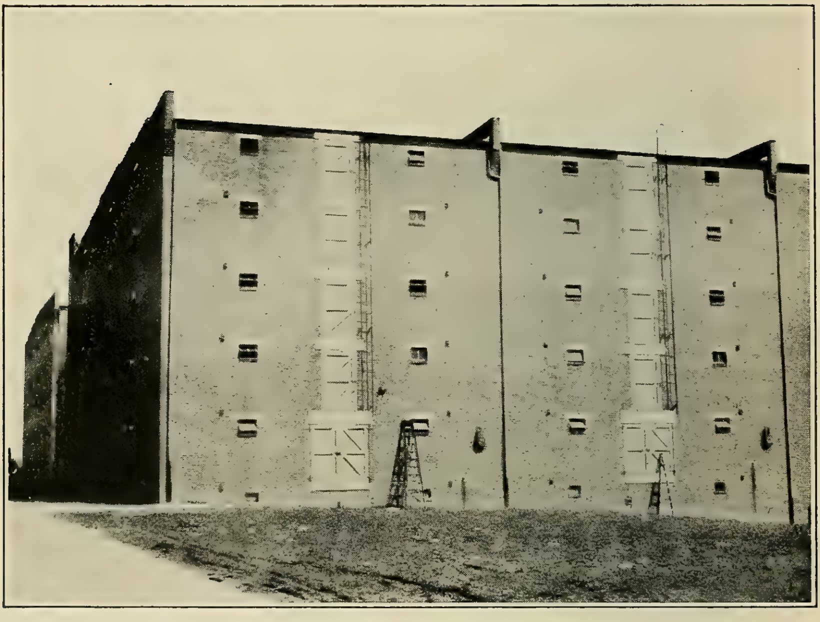
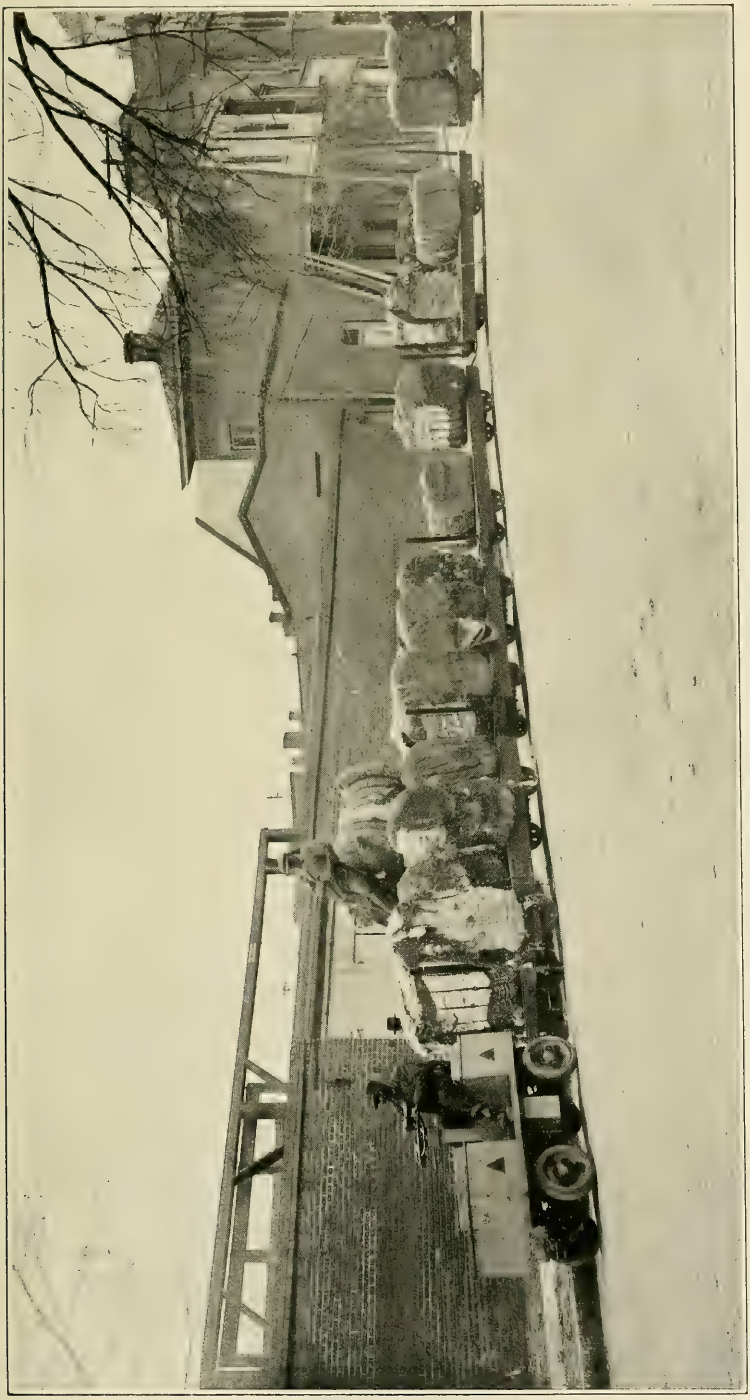
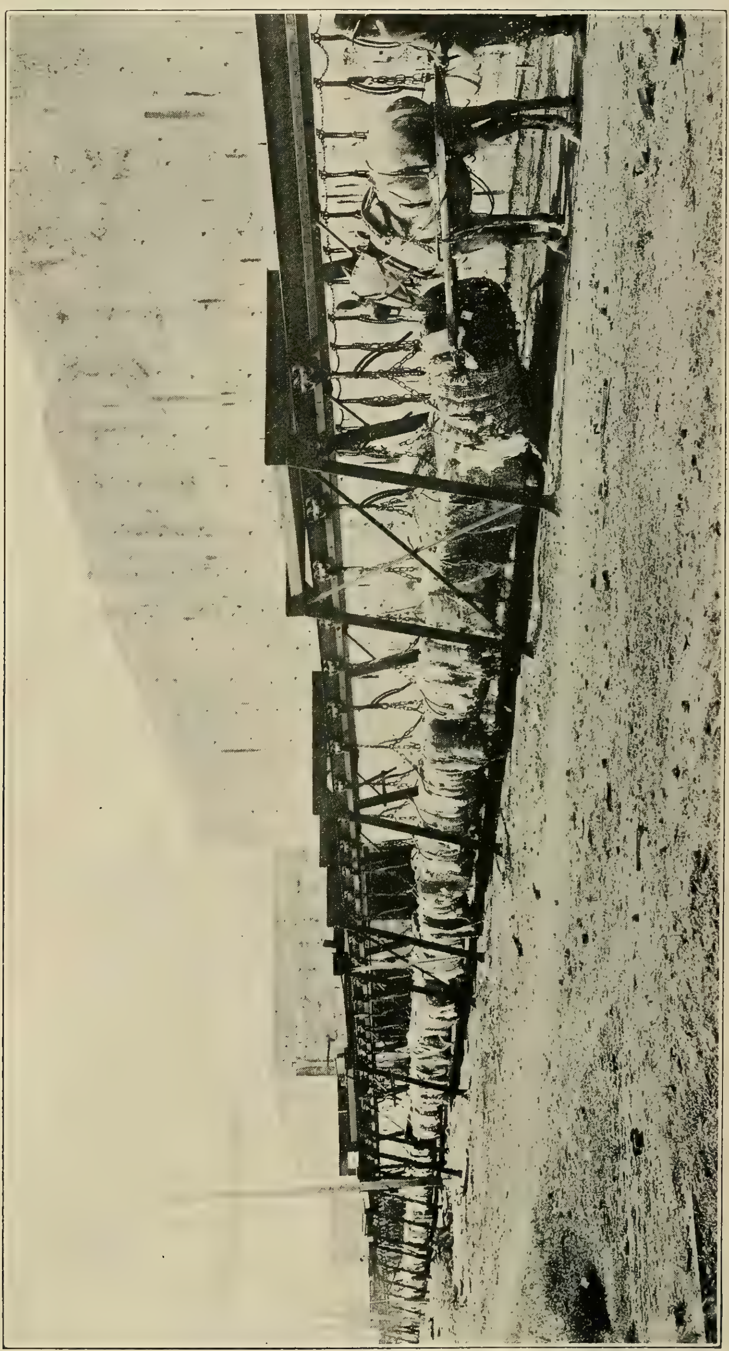


FIG. 2.—A WAREHOUSE WITH DOORS IN REAR WALL FOR USE OF FIREMEN, AND WITH IRON LADDER EXTENDING TO DOORS AND ROOF.



ELECTRIC STORAGE BATTERY TRACTOR DRAWING TRAILER TRUCKS LOADED WITH COTTON.

A variety of such equipment is in use.



AN OVERHEAD TROLLEY SYSTEM SHOWING A LINE OF BALES BEING PUSHED BY A MULE.

When moving down an inclined section of track the mule is not used.

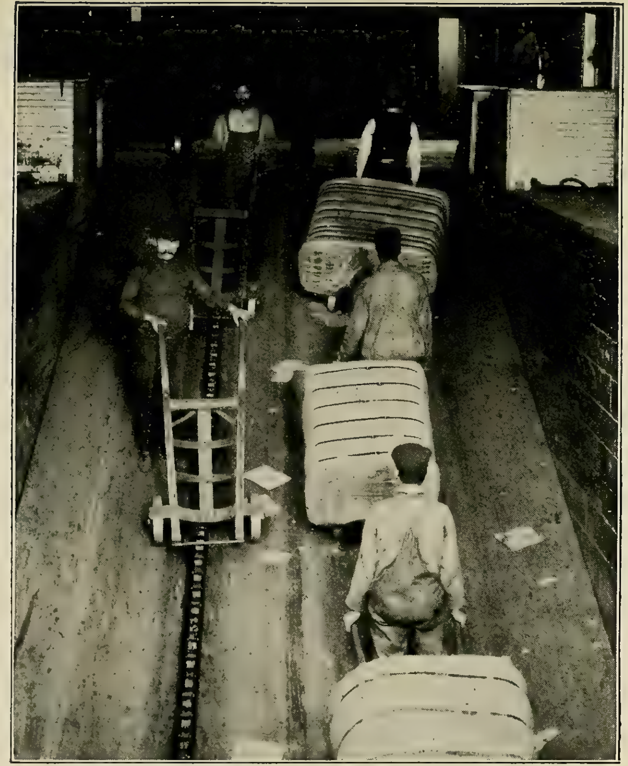


FIG. I.—GENERAL VIEW OF INCLINE CONVEYOR.

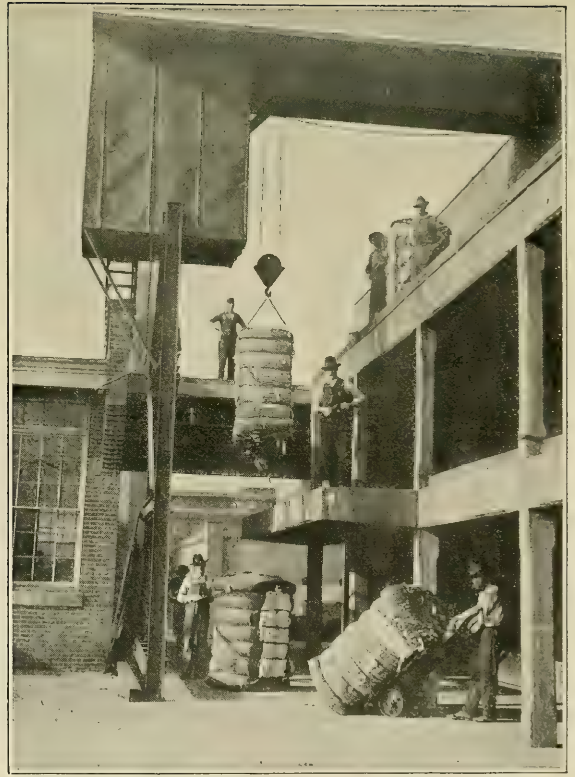
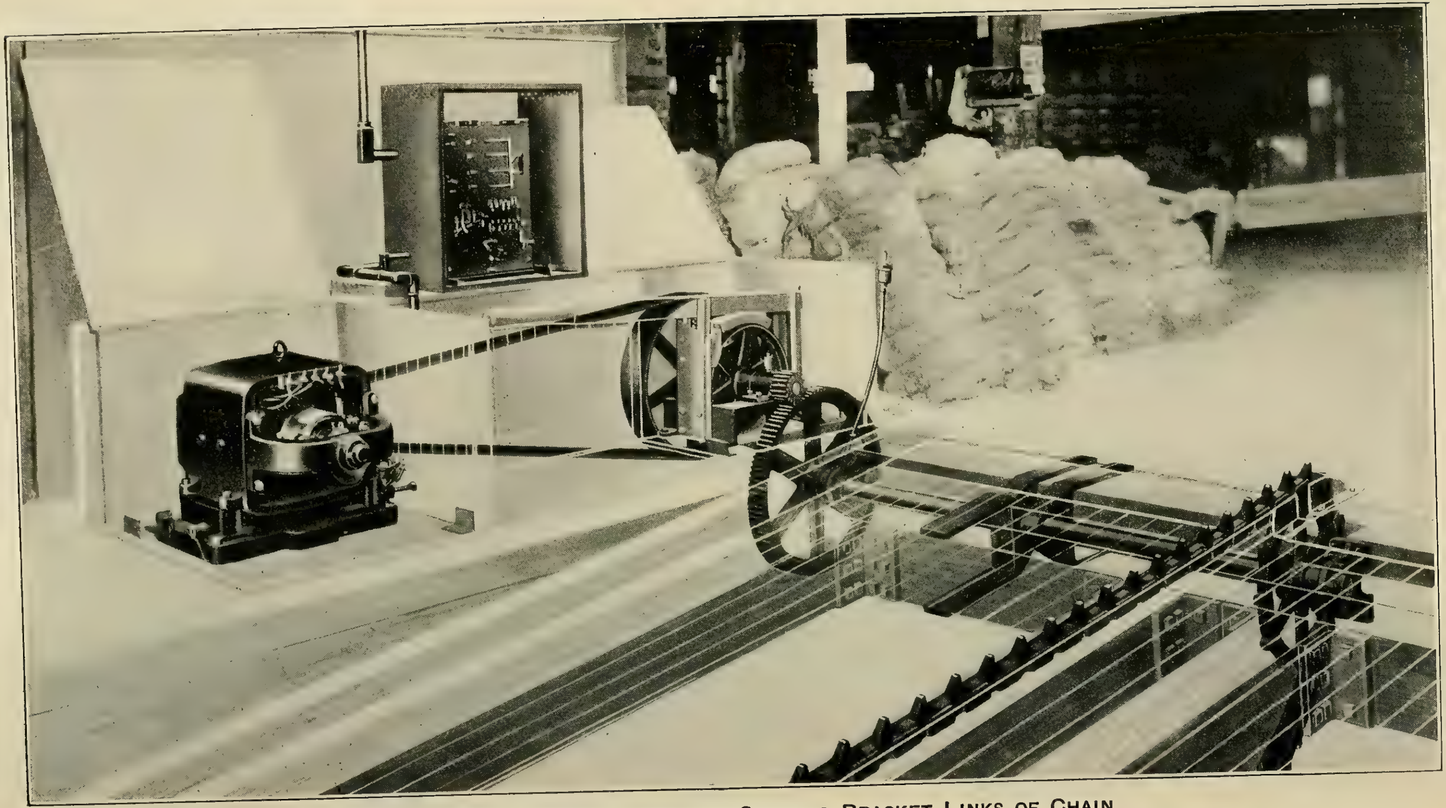


FIG. 2.—OUTSIDE ELECTRIC HOIST IN USE.

This equipment will elevate cotton with great rapidity.

PLATE VIII.



DETAIL VIEW OF INCLINE CONVEYOR SHOWING BRACKET LINKS OF CHAIN.

The chain continues in motion and is always ready for use, though it is readily stopped from either the top or bottom of the incline.

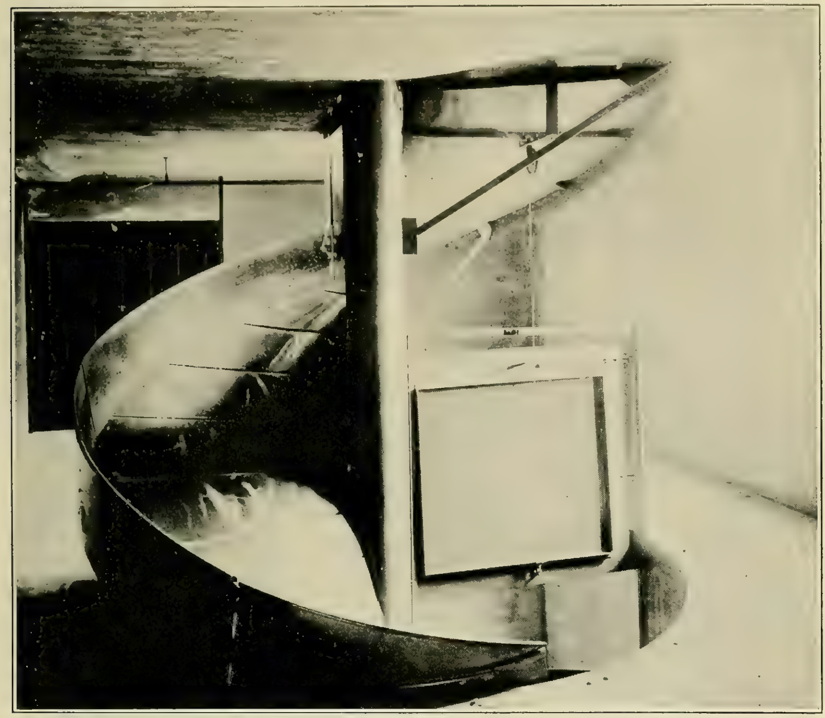


FIG. 1.—SPIRAL CHUTE FOR LOWERING BALES OF COTTON.

Note the fire shutter which is arranged to drop automatically in case of fire. In addition to this precaution chutes should be inclosed by fire walls.

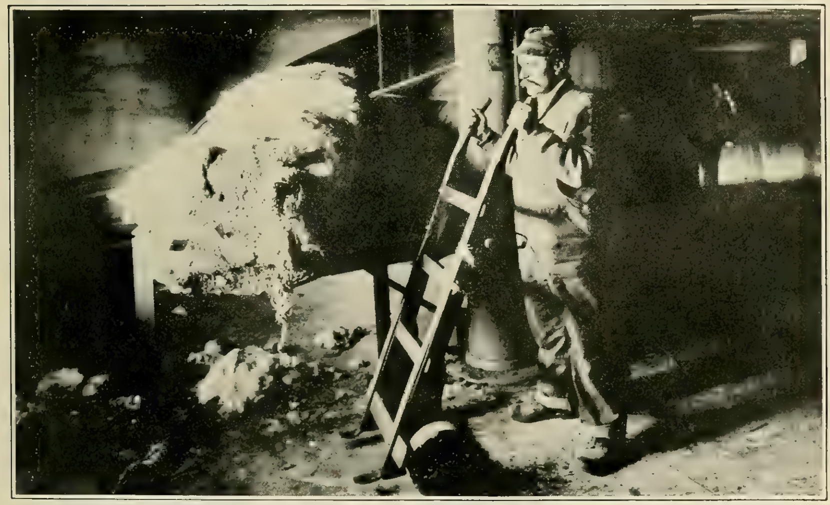
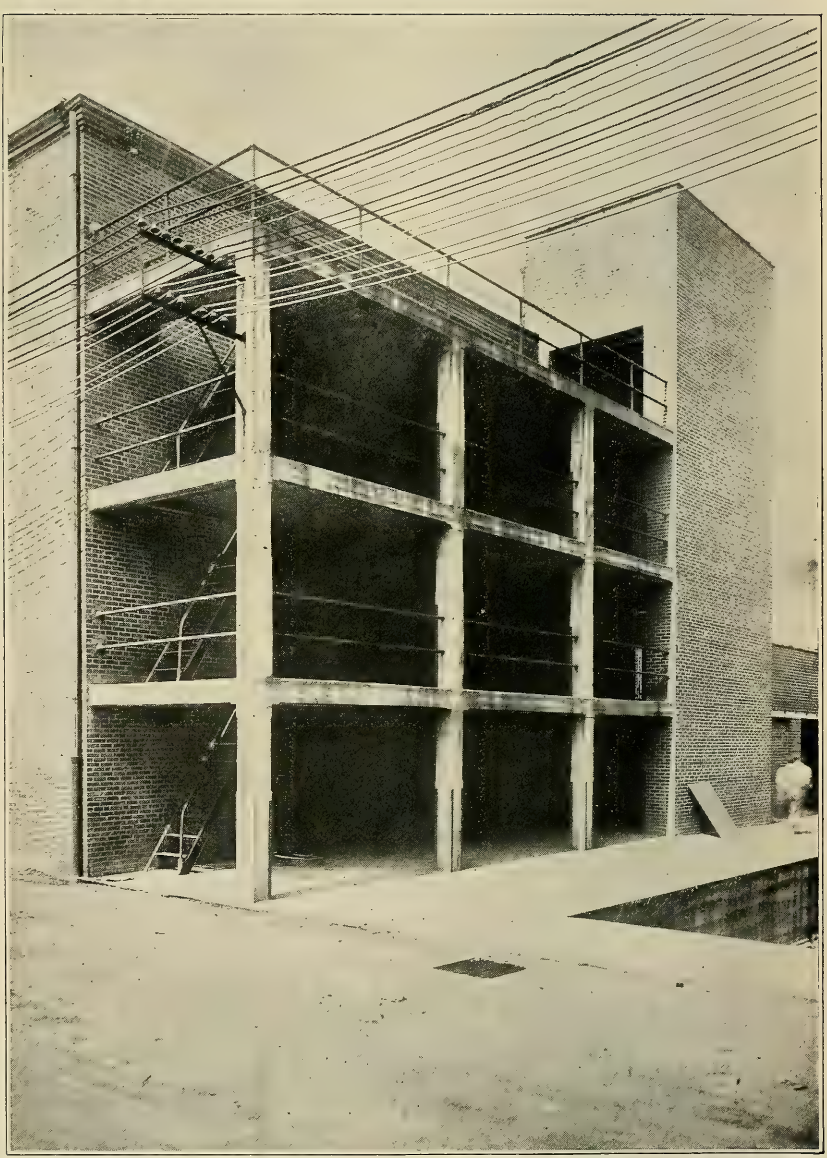
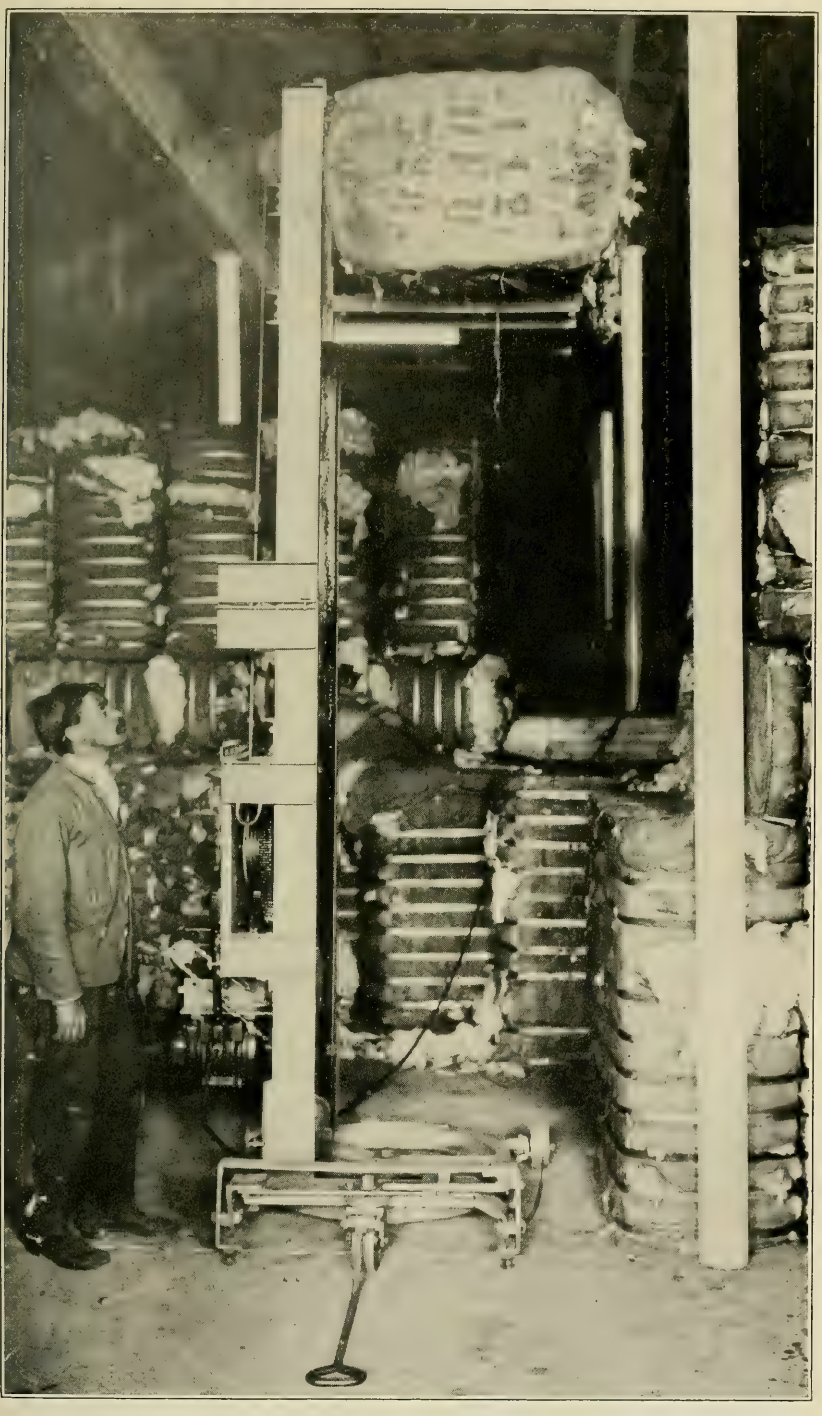


FIG. 2.—THE SPIRAL CHUTE DELIVERS THE BALES AT THE FIRST FLOOR EITHER "HEADED UP" OR IN THE POSITION SHOWN WHICH MAKES LOADING EASY FOR THE TRUCKMAN.



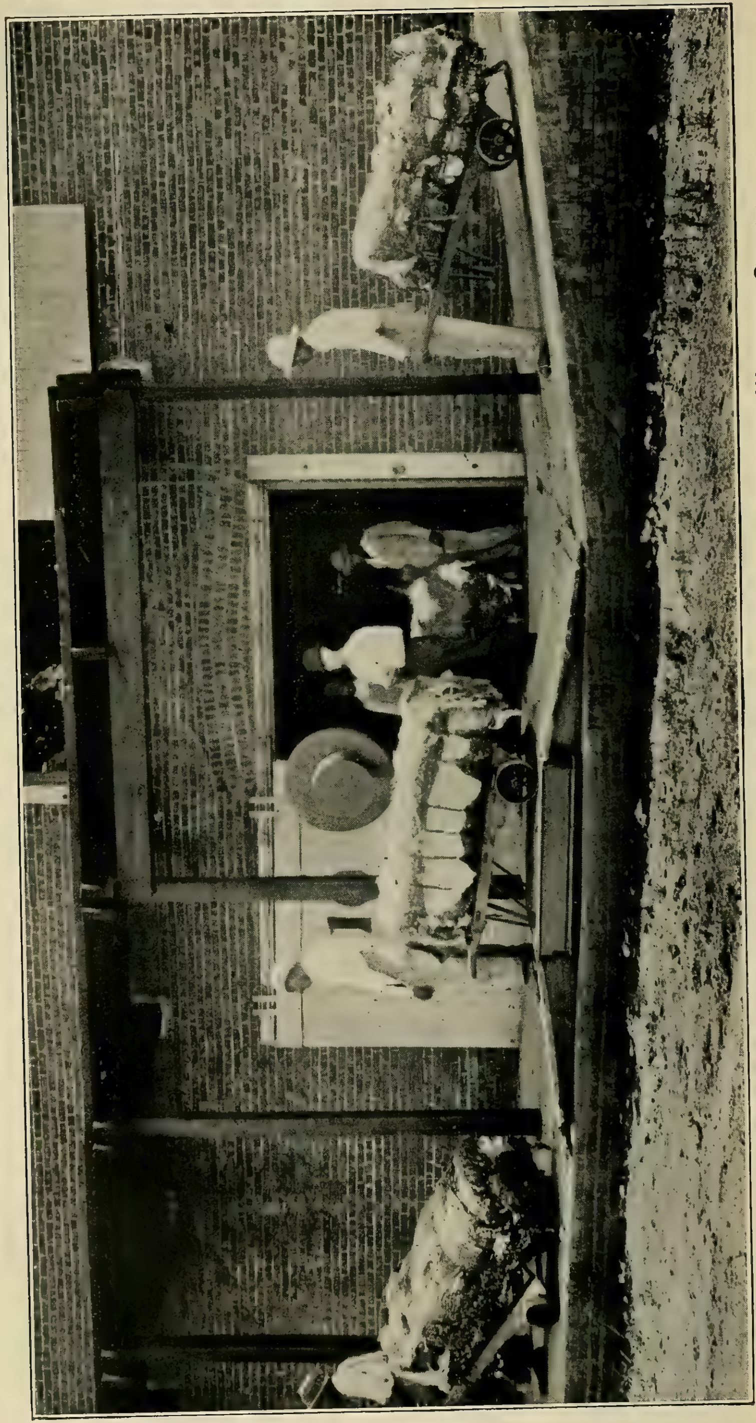
AN EXCELLENT ARRANGEMENT OF ELEVATOR TOWER ON THE EXTERIOR OF THE WAREHOUSE.

Note the neat iron stairs connecting platforms.



THE PORTABLE ELEVATOR, OR PILING MACHINE, MAY BE OPERATED BY HAND OR BY ELECTRICITY.

It is very useful in warehouses where cotton is piled.



A Satisfactory Arrangement for Use of the Platform Dial Scale for Weighing Cotton.

surance standard of volume having a preferred limitation of 72,000 cubic feet, with progressive penalties in rates of insurance when this volume is exceeded. The limitation of volume is probably the fairest method of limiting capacity in bales.[1]

The area and proportions of the compartment should depend upon still other factors, such as economy of cotton handling, cost of construction, adaptation to withstand fire and to permit effective use of water from sprinklers, hose streams and hand appliances, and adequate daylight diffusion.

The most economical method of handling cotton is that of storing the bales one high on end, but for a plant having a large bulk of its business concentrated in a few months of the year this system requires an investment in buildings and site disproportionate to the capacity. It is economical to provide a story height that will permit of tiering the bales of cotton two high on end, or the equivalent, during the rush season, although the deposits remaining for a large part of the year would probably not require the practice of tiering. This latter system is especially suitable for warehouses used as depositories for producers, or for those whose business necessitates a severe peak load of storage. However, the practice of storing single bales on end in a low-story height compartment is very desirable in such plants as maintain storage fairly distributed over the year, or where there are frequent "turnover," or changes, in the bales stored. This arrangement is adapted particularly to the warehouse of several stories in height.

The influence of cost of construction of the compartment is readily appreciated when it is recalled that the floor and roof of the single story compartment usually cost the same regardless of the exact height of the story. Furthermore, the cost of the walls is but slightly more for a story height of 13 feet (which permits tiering two bales high on end or the equivalent) than for a story height of 8½ feet, as a large proportion of the wall cost is in the part of the wall below the floor and above the roof, the cost of these parts being the same in either case. Moreover, where the sprinkler system is used, the cost per bale capacity is practically cut in half where the story height permits two tiers of bales on end, or the equivalent

---

[1] In computing the volume of a compartment the floor area should be considered as extending to the outer side of exterior walls and between centers of division fire walls, while the height should be taken as the average distance from the first floor to under side of the roof plank or slab measured midway between the high and low parts of the compartment, but not including such additional volume as may be inclosed by skylights. In the case of a fire-resistive floor serving as a fire-break between compartments, the vertical dimension should be the distance from the first floor to such fire-resistive floor, or the distance between successive fire-resistive floors.

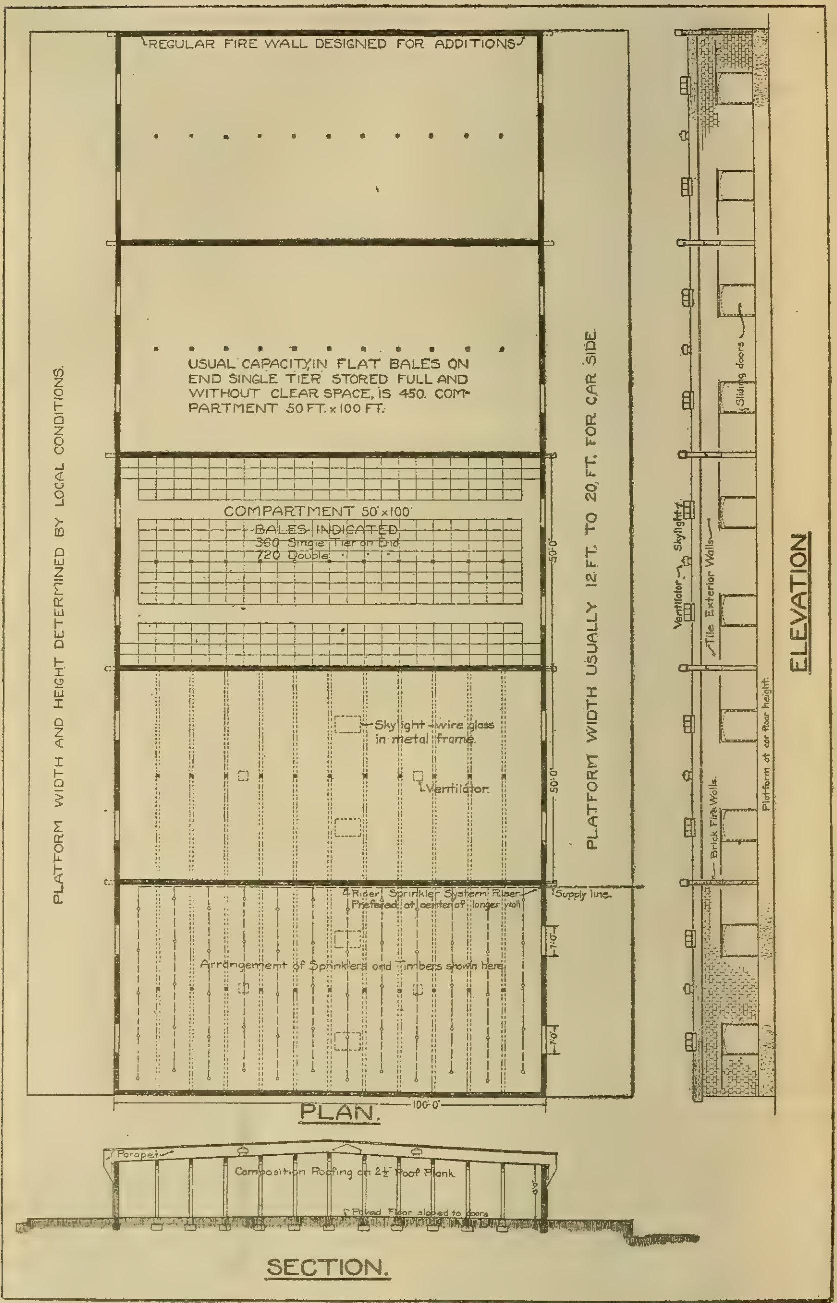

REGULAR FIRE WALL DESIGNED FOR ADDITIONS
USUAL CAPACITY IN FLAT BALES ON END SINGLE TIER STORED FULL AND WITHOUT CLEAR SPACE, IS 450. COMPARTMENT 50 FT. x 100 FT.
COMPARTMENT 50'x100'
BALES INDICATED
360 Single Tier on End
720 Double
Skylight - wire glass in metal frame.
Ventilator.
Rider Sprinkler System Riser Preferred at center of longer wall
Supply line.
Arrangement of Sprinklers and Timbers shown here
50'-0"
50'-0"
7'-0"
7'-0"
100'-0"
PLAN.
PLATFORM WIDTH AND HEIGHT DETERMINED BY LOCAL CONDITIONS.
PLATFORM WIDTH USUALLY 12 FT. TO 20 FT. FOR CAR SIDE.
Sliding doors
Skylight
Ventilator
Tile Exterior Walls
Brick Fire Walls
Platform at car floor height.
ELEVATION
Parapet
Composition Roofing on 2½" Roof Plank
9'-0"
Paved Floor sloped to doors
SECTION.

FIG. 1.—A good design for a warehouse of slow-burning or fire-resistive construction. The size of compartments shown is desirable for nearly all conditions.

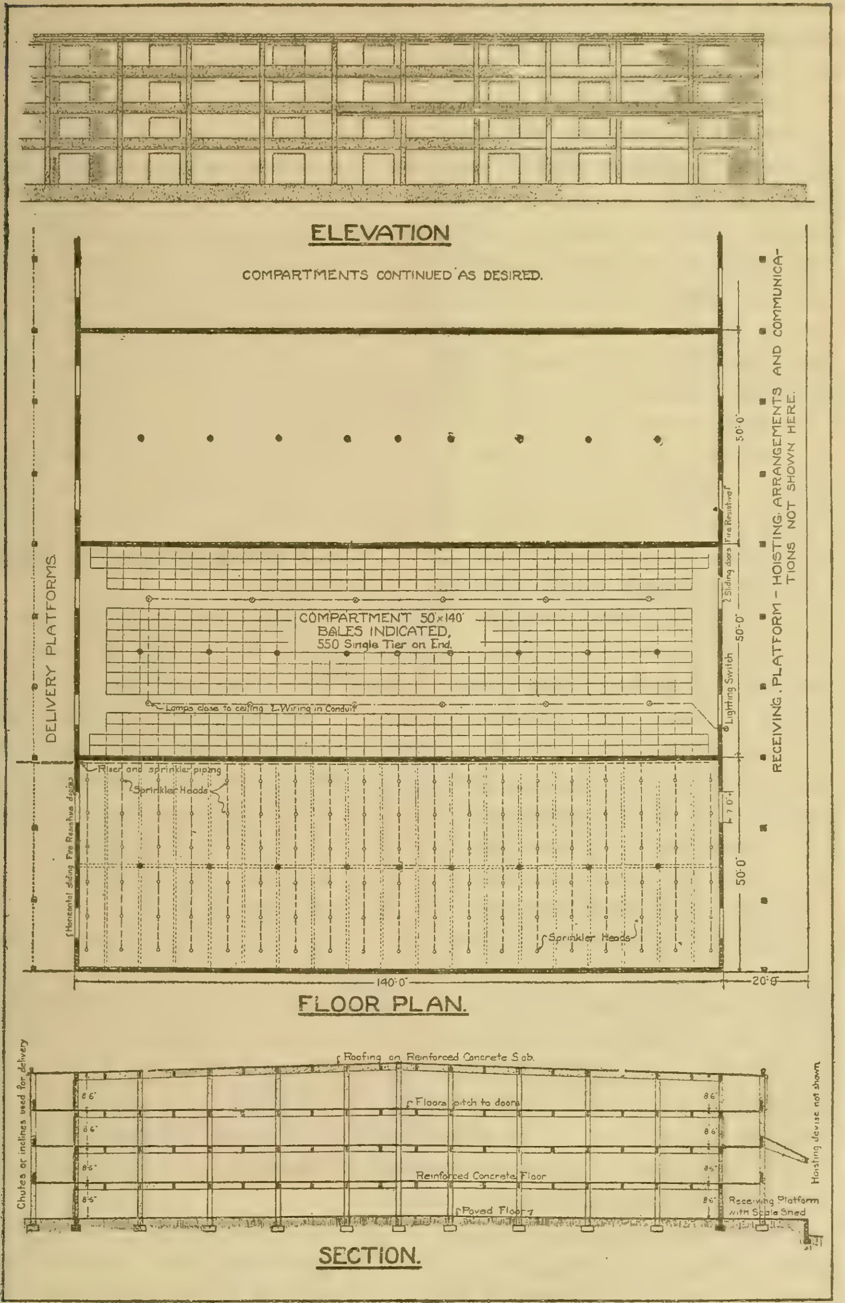

ELEVATION
COMPARTMENTS CONTINUED AS DESIRED.
DELIVERY PLATFORMS.
RECEIVING . PLATFORM - HOISTING. ARRANGEMENTS AND COMMUNICATIONS NOT SHOWN HERE.
50'-0"
2 Sliding doors Fire Resistive
COMPARTMENT 50'×140'
BALES INDICATED,
550 Single Tier on End.
50'-0"
Lighting Switch
Lamps close to ceiling
Wiring in Conduit
Riser and sprinkler piping
Sprinkler Heads
Horizontal sliding Fire Resistive doors
7'0"
50'-0"
Sprinkler Heads
140'-0"
20'-0"
FLOOR PLAN.
Roofing on Reinforced Concrete Slab.
Floors pitch to doors
Reinforced Concrete Floor
Paved Floor
8'6"
8'6"
8'5"
8'5"
Chutes or inclines used for delivery
Hoisting devise not shown
Receiving Platform with Scale Shed
SECTION.

FIG. 2.—A warehouse design suitable for construction of reinforced concrete, or which may be used with timber floors if equipped with automatic sprinklers.

of this with other methods of storage. Again there must be considered the cost of platform, shed, and yard hydrant piping, as well as the land area, all of which unduly increase the cost per bale capacity where the plant is too much expanded or scattered.

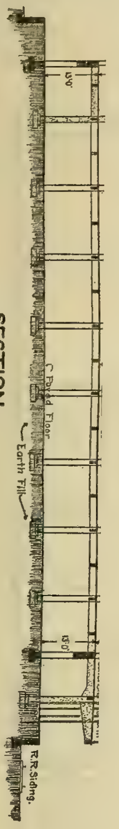
Generally speaking, 100 feet may be considered the best length (between exterior walls) for the warehouse compartment. The height of the compartment, while limited by the floor area as regards allowable volume, should be such as to give a minimum of 18 inches between the surface of the cotton and the under side of overhead beams. Where the sprinkler system is installed, the story height should permit the placing of the spray head at least 18 and preferably 36 inches above the cotton as well as a suitable distance (as later specified) from the ceiling.

It is desirable that the compartment be sufficiently light to allow for reading the tag numbers on the bales of cotton. This is one strong influence in favor of the single story compartment, as skylights can be used to good advantage. Where there are a number of stories, compartments not lighted from above should not exceed 100 feet in length unless lighted by electricity.

The above principles are applied in the accompanying plans. Figure 1 shows single story compartments 50 feet by 100 feet in size having a story height of 13 feet, this being a proportion well suited to any type of construction. Compartments suitable for fire-resistive construction are shown in figures 2 and 3 having story heights of 8½ feet and 13 feet respectively. A rather unusual proportion for the compartment, and one which may be justified only by extraordinary limitations of the site, is shown in figure 4. It is worthy of note that this building may be constructed free of columns, with compartments 30 feet wide by 170 feet long. In the case of two-story compartments, which may be applied advantageously to slow-burning construction, the entire volume between fire walls should be considered as a single compartment from the standpoint of fire hazard. The total volume for two stories is slightly in excess of the preferred standards where floors are 50 feet by 100 feet with a story height of 8½ feet, though this particular arrangement involves but a slight penalty from insurance rates, and, where sprinklered, there is less hazard than in a single story compartment where the bales are tiered.

Where funds for the investment are limited, it often may be desirable to build compartments of such area as will give a volume two, three, or even four times the preferred limit of 72,000 cubic feet. In such case it may be well to construct the compartment with a dimension of 100 feet between exterior walls and space division fire walls at such distances that additional walls can be built in later at

SECTION



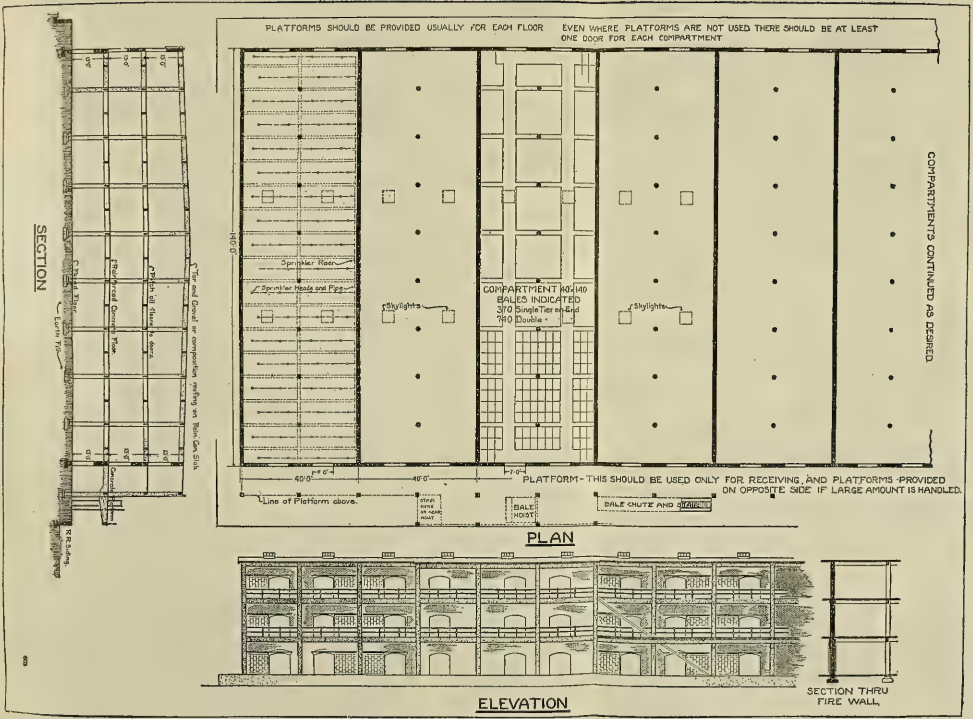

PLATFORMS SHOULD BE PROVIDED USUALLY FOR EACH FLOOR
EVEN WHERE PLATFORMS ARE NOT USED THERE SHOULD BE AT LEAST ONE DOOR FOR EACH COMPARTMENT
COMPARTMENTS CONTINUED AS DESIRED.
140'0"
Sprinkler Riser
Sprinkler Heads and Pipe
Skylights
COMPARTMENT 40'x140
BALES INDICATED
370 Single Tier on End
740 Double
Skylights
40'0"
40'0"
7'0"
7'0"
PLATFORM - THIS SHOULD BE USED ONLY FOR RECEIVING, AND PLATFORMS PROVIDED ON OPPOSITE SIDE IF LARGE AMOUNT IS HANDLED.
Line of Platform above.
STAIR HERE OR NEAR HOIST
BALE HOIST
BALE CHUTE AND STAIR
PLAN
SECTION
13'0"
13'0"
13'0"
Paved Floor
Earth Fill
Reinforced Concrete Floor.
Pitch all floors to doors.
Tar and Gravel or composition roofing on Rein. Con. Slab
Concrete Platform
R.R. Siding.
ELEVATION
SECTION THRU FIRE WALL.

FIG. 3.—A warehouse design suitable for construction of reinforced concrete.

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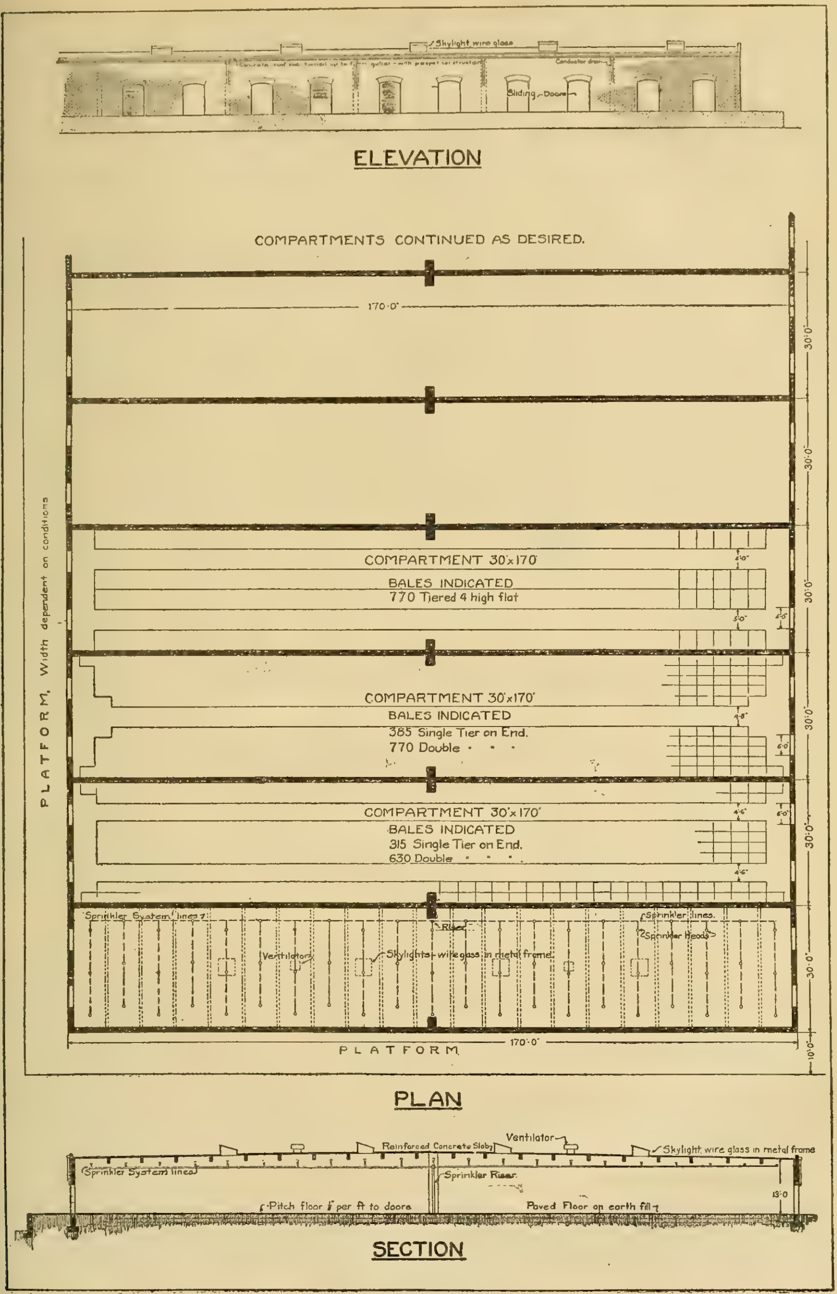

FIG. 4.—A warehouse design having long compartments free of columns.

intervals of 50 feet forming compartments 100 feet by 50 feet in size. When the building is first planned the story height should be so fixed that compartments thus formed will have a volume not exceeding the preferred limit of 72,000 cubic feet. Thus a building may be constructed which has a low first cost but which may be improved very economically later with an effective saving of fire hazard and insurance charges. Another desirable method of reducing first cost and yet providing for future improvements is to use a story height of 17 feet (at the eaves) and provide corbels or pockets in the walls to support a second floor to be built in later. In this way automatic sprinkler protection can be given to a large capacity and later the added floor and discontinuance of tiering will secure convenience and economy in handling and advantageous protection for the cotton. The sprinkler system would have to be extended so as to cover the lower floor. This should be anticipated in the beginning and supply pipes made large enough to care for the additional heads.

The compress compartment demands, for practical use, a greater area than is recommended for the storage compartment. Here tiering of cotton is not to be countenanced from the standpoint either of practical cotton handling or fire hazard. However, requirements for good light and ventilation, as well as the convenient operation of some types of weighing apparatus in use, make a story height of approximately 15 feet desirable. For these reasons the capacity permissible is better expressed in terms of square feet of floor area. This area usually should not exceed 22,500 square feet, this being equivalent to a floor 150 feet square. Where this space is not sufficient, a similar compartment may be provided adjacent to the compress compartment and communicating with it through well protected fire doors in the dividing fire wall.

Arrangements for the compress compartments are shown in figures 5 and 6. Figure 5 shows how the compress may be divided into six compartments, all communicating directly with the compress compartment, without openings in the fire walls except for those doors leading directly to the press room. These arrangements provide for a detached boiler room which is always to be desired, though a corner of the press room may be cut off by fire walls for this use. The second plan (fig. 6) provides compartments on each side of the press compartment. Both of these plans may be adapted readily to either fire-resistive or slow-burning construction. If slow-burning construction is used, roof openings such as skylights should be of metal, and wooden monitors should be placed at least 50 feet from fire walls.

The types of construction which are desirable for the warehouse building are fire-resistive, slow-burning, and a modification of this

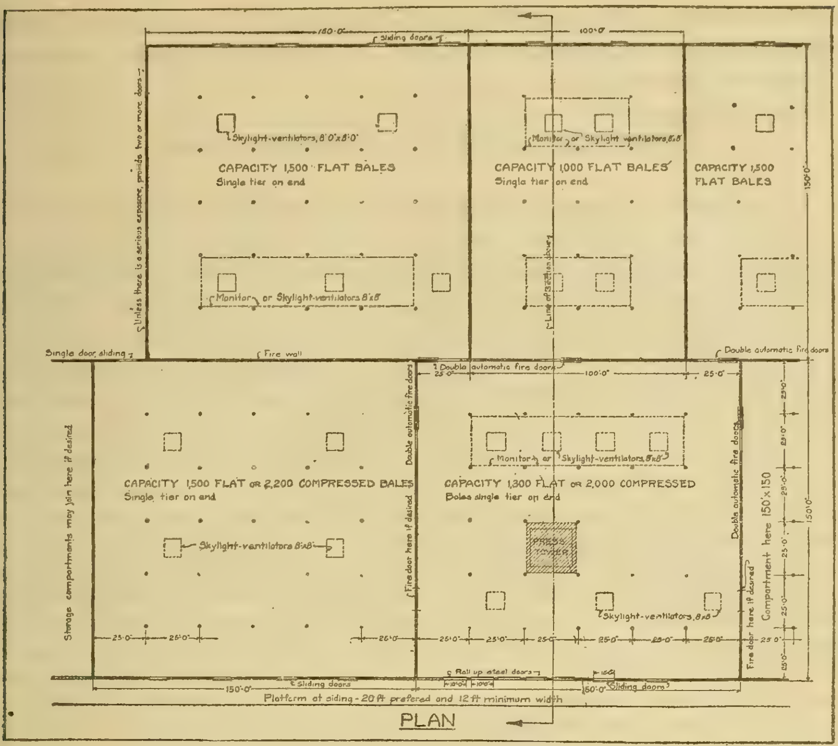
180'-0"
Sliding doors
100'-0"
Unless there is a serious exposure, provide two or more doors
Skylight-ventilators, 8'0"x8'0"
CAPACITY 1,500 FLAT BALES
Single tier on end
Monitor or Skylight-ventilators 8'x8'
CAPACITY 1,000 FLAT BALES
Single tier on end
Monitor or Skylight ventilators 8'x8'
Line of section above
CAPACITY 1,500
FLAT BALES
150'-0"
Single door sliding
Fire wall
Double automatic fire doors
Double automatic fire doors
100'-0"
25'-0"
Storage compartments may join here if desired
CAPACITY 1,500 FLAT OR 2,200 COMPRESSED BALES
Single tier on end
Skylight-ventilators 8'x8'
Fire door here if desired
CAPACITY 1,300 FLAT OR 2,000 COMPRESSED
Bales single tier on end
Monitor or Skylight-ventilators 8'x8'
PRESS TOWER
Skylight-ventilators 8'x8'
Double automatic fire doors
Fire door here if desired
Compartment here 150'x150
25'-0"
26'-0"
Roll up steel doors
Sliding doors
150'-0"
Sliding doors
Platform at siding - 20 ft prefered and 12 ft minimum width
PLAN

FIG. 5.—A compress arrangement which permits of access to five compartments without their connecting with each other.

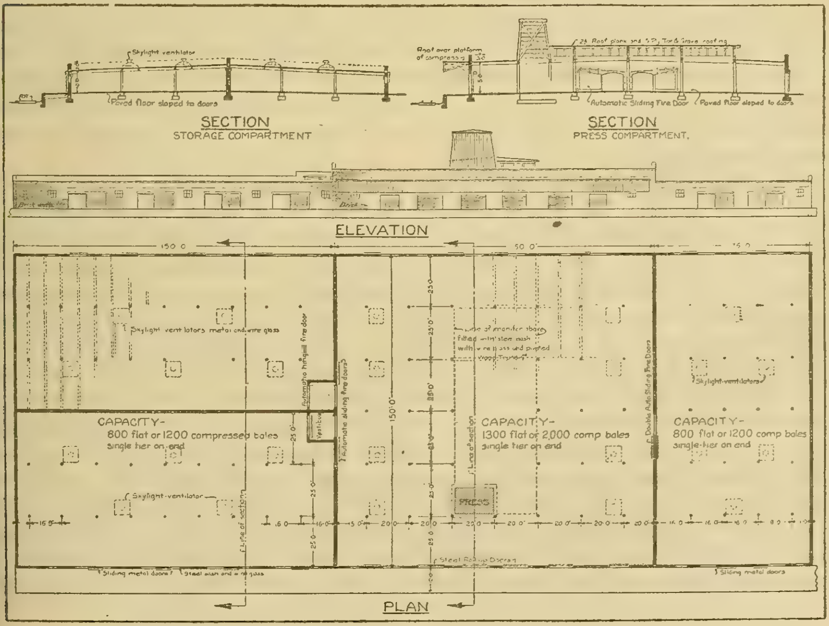
Skylight ventilator
Paved floor sloped to doors
SECTION
STORAGE COMPARTMENT
Roof over platform of compress
Roof plank and Tar & Gravel roofing
Automatic Sliding Fire Door
Paved floor sloped to doors
SECTION
PRESS COMPARTMENT.
ELEVATION
150'0"
50'0"
Skylight ventilators metal and wire glass
Automatic hinged fire door
Automatic sliding fire doors
150'-0"
Line of monitor above
CAPACITY-
800 flat or 1200 compressed bales
single tier on end
Skylight-ventilator
Line of section
CAPACITY-
1300 flat or 2,000 comp bales
single tier on end
PRESS
Double Auto Sliding Fire Doors
Skylight-ventilators
CAPACITY-
800 flat or 1200 comp bales
single tier on end
Steel Roll up Doors
Sliding metal doors
Steel sash and wire glass
Sliding metal doors
PLAN

FIG. 6.—A good arrangement for compress and adjacent storage compartments. Additional compartments may be continued at either end of the building.

type which may be called semi-slow-burning (or "wood-end") construction. In addition to these, there is the less desirable frame and "iron clad" construction.[1]

FIRE-RESISTIVE CONSTRUCTION.

Fire-resistive—sometimes called "fireproof"—construction for the warehouse ranks first both in protection against fire and in low cost of maintenance and depreciation charges. However, the first cost is more than that for the other types of construction. For this reason it is not to be preferred usually to the best design of slow-burning construction, for single story warehouses. On the other hand, fire-resistive construction should be used for warehouses several stories high whenever possible, and for the single story plant which is badly congested or severely exposed. Discussion of fire-resistive construction is taken up first so as to treat fully such subjects as masonry and other details common to the several types of construction.

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[1] The adaptation of the compartment to withstand fire and admit of effective use of fire protective equipment is of great importance. The features of construction will be discussed under that heading, but it may be stated here that effective use of hose streams demands that the length of the compartment, or the distance between exterior walls, usually should not exceed 100 feet. Exceptions to this rule are the cases of fire-resistive construction where there is but one story with large skylights through which streams of water may be thrown to the center of the building, and where the construction is fire-resistive, of several stories and fully protected by sprinkler equipment. In the latter case the increased length of the compartment would be desirable in order to reduce the cost of the platforms. In this case the compartment length (between exterior walls) should not exceed 150 feet.

Compartments may be combined horizontally in considerable numbers, the only limitation being that single combinations constituting one building should not be so long that in case of fire it would require an unreasonably long time for a fireman or other person to pass around the building from one side to the other. Usually the building should not exceed 700 feet in length, and there should be an open space between the ends of these buildings of at least 50 feet, unless the exterior walls are of substantial masonry, in which case a 25-foot space is sufficient.

The whole consideration of size of compartments is, of course, an effort to restrict fire damage. Any definite limit is necessarily arbitrary. The limit of 13 feet in story height is well adapted to the storage of flat cotton two bales high on end or one tier on end and two tiers flat, and is a suitable proportion where bales are stored entirely on the side as is frequently the case for compressed cotton, bales in this position are piled five high. In this latter case additional story height results in less effective use of automatic sprinkler (see section on fire protection), and other fire-extinguishing equipment to such an extent that the maximum should not exceed 18 feet. There should also be taken into account the fact that usually with the increased height, additional cotton is subjected to fire. As previously stated, the best distance between exterior walls is 100 feet and this should not be exceeded except under conditions similar to those explained, and in no usual case should the distance exceed 200 feet. The remaining dimension for the compartment—the distance between division walls—may be adjusted entirely in reference to the value of cotton thus subjected to a single possible fire. Preferably this dimension should be such as to limit the volume of the compartment to 72,000 cubic feet.

DISTINCTIVE ADVANTAGES AND FEATURES.

Essential features of fire-resistive construction are the superior fire-resistive nature of material used in construction of all walls, floors, roof, structural members and details, together with such arrangement and assembly of this material as will protect the contents of the building against fires of external origin and the spread of fires originating inside, and will result in minimum damage to the building itself. It should be noted that any type of building in which combustible material is stored may be subjected to the most severe test from internal fires. Therefore the construction of the building should be such as to withstand an intense and sustained fire and, at the same time, afford the best opportunity for use of fire-protective equipment. The important features of this construction may be considered as the division fire walls, exterior walls, roof, floors, and openings.

TYPES OF WALLS.

Until comparatively recent years all walls supported their own weight and usually a part of the load imposed by roof and floors. This type of wall is known as a "bearing wall." It is the type generally used for the cotton warehouse, both as the division fire wall between compartments and as the exterior wall where this is of masonry. With the introduction of the steel and reinforced concrete buildings there came into use two other types of wall—the "curtain wall" and the "panel wall." The curtain wall, which merely carries its own weight, is often used in commercial buildings, though it is seldom used in the cotton warehouse; when it is so used, the same limitations fixed for the bearing wall will be found applicable. The panel wall is especially well suited for reinforced concrete construction and so presents advantages for some warehouse designs. In the usual construction, the wall is built in panels formed by the structural frame, the portion inclosing any story being supported independently. Division fire walls and exterior walls, for fire-resistive construction, present somewhat different requirements and therefore are discussed separately. In both instances, thickness and other provisions stated are based on brickwork and refer to the usual bearing wall, while modifications of these requirements are stated in connection with other materials and the different designs of walls.

DIVISION FIRE WALLS.

Division fire walls should extend from a firm foundation of concrete or other masonry to the underside of the roof, but need not extend through the roof. The end of the division fire wall may be built into the exterior wall where this exterior wall is of material equal to that used in the division fire wall; but if the exterior wall is of even slightly inferior material, the division fire wall should extend through to the outside of the exterior wall. Otherwise, division fire walls for fire-resistive construction are not essentially different from division walls for other types of construction. The division fire wall for a building of several stories may be constructed solidly with floors resting on offsets (or corbels), or reinforced concrete floors may extend through the wall.[1]

The proportions and design of the division wall should be adapted to the general design of the buildings and the material available for the wall. In no case should the division wall be less than 16 inches in thickness except for reinforced concrete panel walls referred to later. With this as a minimum, walls of concrete properly reinforced with steel may be 4 inches less in thickness than is required for brick, while walls of plain concrete should be 4 inches thicker than the nominal thickness required for brick because of the fact that severe or concentrated heat will produce such unequal expansion in a thin wall as would be likely to cause dangerous cracks or crumbling.[2]

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[1] The requisites for material for the construction of a division fire wall are, first, that it will not transmit heat rapidly; second, that it will not deteriorate under the test either of quick and severe or of sustained fires; third, that it will absorb heat with sufficient uniformity to obviate dangerous difference in resulting expansion between the protected side of the wall and the side exposed to fire. Even with the best materials it is essential that the proportions and design of the wall be such as to resist the stresses resulting from the fire and give sufficient stability to the wall.

Material best suited for division walls are hard brick (of clay or clay and shale) laid in cement mortar, reinforced concrete, or plain concrete. All of these materials offer a strong resistance to the transmission of heat and are not deteriorated by it to a dangerous degree. Furthermore, they absorb heat with sufficient uniformity to prevent variation in expansion which results in spalling, or the flaking off of large pieces. These are qualities lacking in many stones, especially limestones and granites; limestone will crumble when subjected to heat and granite will break up badly. It is for this reason, chiefly, that division walls should not be constructed of stone. Mortar composed largely of lime deteriorates from heat, and, therefore, brickwork should be done with cement or cement-lime mortar.

It is the requisite that a material absorb heat and expand uniformly that is the chief objection to the use of hollow clay tile in division fire walls. The feature of insulation formed by the air pockets or cells—which makes this material so desirable for certain uses—totally unfits it for use in a division wall. During a fire, the exposed shell of the tile expands very rapidly and the air cell prevents sufficient absorption of heat by the protected portion of the tile, with the result that the thin shell cracks or the wall buckles because of the excessive expansion of one side.

The proper increase in thickness for a division fire wall beyond that set as a minimum depends largely on the height and number of stories and the length (unbraced) of the wall. Discussion of the thickness has reference to brick bearing walls, while the provisions for other material and designs explain the modification such change would involve. The number of stories and their height should be the first consideration in determining the thickness, and should be based on a wall not exceeding 100 feet in length. For a single story building having a story height not exceeding 18 feet at the lowest or 20 feet at the highest part of the roof adjacent to the division wall, such wall should be 16 inches thick, while for every additional 12 feet or fraction thereof in height this thickness should be increased 4 inches. If the wall is several stories in height, the minimum wall thickness for the two top stories should be 16 inches, while for each two successive stories below (each not over 15 feet

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Where tile is used as panel walls in a frame of reinforced concrete or between piers of concrete or heavy masonry, this danger is intensified because the tile is securely restrained by the piers or concrete frame which expands much more slowly with the result that the tile is subjected to an expansive stress which is likely to destroy it. The idea that the tile is destroyed by the formation of steam at such pressure as to cause an explosion is not tenable for the reason that sufficient moisture is not always present and, where it is, the mortar joints are rarely sufficiently tight to prevent the escape of steam as it forms. The cracking of tile when water is applied is due to uneven contraction from sudden cooling. These statements appear in conflict to the use of tile for insulation of steel frame buildings. This, however, is a use where the arrangement of the tile permits more expansion as it is less restrained, and usually the fire is less severe. However, experience has shown that even here clay tile affords much less protection than brick or concrete, which now is being used for protecting important columns.

[2] This action in a concrete wall adequately reinforced with steel would not occur to a serious extent, while in a brick wall the bonding or tying together of the face or outside brick would result in a decided tendency to limit the penetration of the damage to the outer 4 inches of the thickness of the wall. Furthermore, the wall of unreinforced concrete affords a chance for concealment of dangerously poor workmanship which the introduction of steel reinforcement would tend to overcome. The thickness of 12 inches, or even 10 inches for reinforced concrete panels, is entirely satisfactory in retarding the passage of heat, though it must be increased when required by certain conditions.

in height, from floor surface to floor surface) or each increment of 30 feet, the wall should be increased in thickness 4 inches.[1]

The foregoing thicknesses apply to a wall not more than 100 feet long. If this length is exceeded the thickness of the wall should be increased 4 inches throughout for each additional 100 feet or part thereof, except that for reinforced concrete the increased thickness may be one-half that stated above.[2]

While it is not intended to discuss here the matters pertaining to all details of a building code, it may be well to point out some dangers of poor construction in the division fire wall. Openings in division fire wall should be avoided as far as possible. It seldom is necessary to provide any openings in such a wall of a warehouse storage compartment, though openings frequently are necessary in compress compartments to connect them, or to connect the compress with the adjacent storage compartment. In any case the opening should be as small as is practicable and should conform to the limitations stated later in the discussion of the doors themselves. Construction and design of fire doors is discussed in detail later.[1]

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[1] For the final 4 inches of thickness in excess of 16 inches pilasters may be substituted provided such pilasters are built with the wall, are opposite each other on both sides of the wall, and are located and proportioned suitably. Such pilasters should have a projection from the wall of 4 inches on each side, and the face (or dimension parallel to the wall) should be a minimum of 16 inches and not less than one-eighth of the spacing of the pilasters measured between centers. The spacing of pilasters should not exceed 25 feet. The location should be such that no part of the wall will be loaded beyond the allowable unit working stress of the material used.

[2] While stated thicknesses for walls seem arbitrary, the explanations made show that a division wall is subjected to more severe tests during a fire as the height or length of the wall increases. Difference in thickness of brickwork necessarily must be made in units of 4 inches, and so heights and lengths of walls stated are adjusted to this variation. Good practice has shown that the above thicknesses are very satisfactory for a wall serving as a barrier against fairly intense and continued heat. A wall of less thickness may afford good protection, but it should be borne in mind that a division fire wall should represent "the last line of defense" in a fire; and if the values behind the wall justify the expense of a wall, then one which will afford dependable protection is the best investment.

An exception to some of the foregoing requirements for a division fire wall is found in panel-wall construction especially adapted to reinforced concrete roof and floors. The panels may be built of brick between supporting columns and floor and roof slabs or beams, after these have been constructed, or the panels may be of reinforced concrete cast with the floors. In such a case the stability of the wall and its action in resisting expansion is cared for by the concrete framework, and each panel of brickwork may be treated as a separate and independent division wall in applying the preceding requirements. These requirements for thickness, however, may be modified to the extent of permitting a brick panel wall to be only 12 inches in thickness, or a reinforced concrete panel 10 inches in thickness, for a height of 20 feet for panels not exceeding 30 feet in length. The mortar used for laying brick walls of this character should be the cement-lime mortar described, as it is more compressive, and so in this confined position may withstand the severe compression from expansion. This form of construction usually will not be economical as compared with the regular division wall carrying the floors and roof, except in case the building is more than four stories high or the wall is excessively long or there are such special conditions as are discussed under the heading of roof and floor construction.

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[1] If brick is used they should be well burned and at least two-thirds of them hard (or fully burned), the "run-of-kiln guaranteed two-thirds hard" being satisfactory. Care should be taken to see that extremely soft brick from the outside of the kiln are thrown out. The harder brick of the lot should be used for the exposed surfaces of the wall, and the softer brick used for filling in between.

The brick should be laid fairly close together with joints well filled with mortar. Ample "bond" or "header" courses should be used to tie the parts of the wall firmly together, this tie being used for every sixth course. The work should not be carried on in freezing weather, while if the weather is warm and dry the brick should be wet before they are laid, as this prevents too rapid drying of the mortar. The mortar used for the fire wall preferably should contain a mixture of one part Portland cement, one-seventh part lime (either putty or hydrated), and sand not exceeding three parts, and should be mixed only as required for use. A fairly satisfactory mortar for use above the ground, however, may contain one part Portland cement, one part lime (either putty or hydrated) and six parts sand. Cement should not be added more than one-half hour in advance of use of the mortar.

When concrete is used, it should be prepared under competent supervision, while the actual work can be done largely by unskilled labor. Mixing and casting should not be done in freezing weather. Concrete not reinforced with steel should contain one part of Portland cement, two and a half or 3 parts sand, and five parts of suitable gravel or crushed stone. The chief dangers to be guarded against are leakage of the form in which casting is done, insufficient mixing, and careless packing or tamping. Concrete reinforced with steel, as used for walls, should conform to the requirements later stated in reference to "Reinforced concrete." The top of the opening should be formed by a substantial brick arch or a concrete lintel. Steel or iron lintels may be used provided they are protected by either 4 inches of brickwork or a complete overlapping of the door. The threshold should be of iron or steel, securely anchored, or the sill (including the part against which the door closes) may be of concrete 6 inches or 9 inches thick and fully supported by the wall. An example of 4 by 4 inch steel angles used with concrete is shown by Plate XIV, figure 5. A solid cast-iron threshold with the surface roughened is to be preferred. The threshold should be raised 1½ inches or 2 inches, with the floor sloped up to this level, so that water used to extinguish fire in one compartment will not flow into the one adjoining.

Vestibule doorways afford excellent protection of the opening. An example of such an arrangement is shown by Plate XIV, figure 6, where the low story makes the arrangement shown fairly economical. Where the story is very high the vestibule may be constructed with a low ceiling covering slab. The width of the vestibule corresponds to the width of doors, while for the depth, or distance provided between the doors, 6 feet is sufficient unless it is desired to use one swining door opening into the vestibule, as is shown by the drawing. In such sase the minimum distance of 6 feet would be increased to suit the width of door used.

EXTERIOR WALLS.

The exterior wall of the fire-resistive warehouse should be of noncombustible material. It need not, however, be of such material and design as to offer as long-sustained resistance to fire as the division wall unless that particular exterior wall has a very hazardous exterior exposure, in which case it should conform to requirements for a division fire wall. The material suitable for the usual exterior wall is not as limited as is the case for the division fire wall. Brick, concrete (with or without steel reinforcement), stone, and sand-lime brick are all acceptable, and usually are to be given preference in the order named. Where there is no exposure hazard, hollow cement blocks and hollow clay wall tile may be used for panel walls of two-story buildings, but even in this case the adoption of this material for a fire-resistive warehouse is not desirable.[1]

In discussing exterior walls, brickwork is the basis for stating thickness, just as it is for the division fire wall, but in this case no increased thickness is required when plain concrete is substituted for brickwork. (In this connection it is well to note the requirements for "panel walls" set forth later.)

The exterior wall of the usual bearing type which supports floors and roof may be 4 inches less in thickness than was specified for a division fire wall, provided the minimum thickness be 12 inches for the first story, where the height of the story does not exceed 18 feet, and that where there is more than one story the wall for the top story should not be less than 12 inches thick. In applying the rule for increased thickness for long walls, only that portion of the exterior wall which is between division fire walls need be considered.[1]

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[1] Brick, cement blocks, and stone may be laid in lime mortar, except that for the portion of the wall below and 2 feet above the ground level, the cement mortar, previously mentioned, should be used. The lime mortar should contain one part lime putty, or hydrated lime, to not more than four parts sand, the exact proportion being adapted to the character of the sand used. (See U. S. Bureau of Standards Circ. 30; Lime: Its Properties and Uses, 1911.) The replacement of one-fourth of the lime with a like amount of Portland cement will give excellent results without a great increase in cost. In this case the mortar may be mixed in advance and the cement added as the mortar is used. These mortars are equally suitable for the cement blocks.

Walls of brick—either clay, clay and shale, or sand-lime—and of concrete with and without reinforcement may be used to support the roof and floor, this construction being a "bearing wall." In case of walls of cement blocks or clay tile it is best that the floor and roof slab be supported independently by columns and beams and that the wall be built independently so as to be tied to the floors and columns in such manner that the wall will support only its own weight, thus forming a "curtain wall." In case the building is a number of stories in height and the tile or blocks are used it will be better and more economical to use a "panel wall" built between the columns and beams in such manner that the inclosing wall for any floor is supported by that floor and not by the wall for the story below.

Windows in the exterior wall should consist of steel sash glazed with wire glass and should be stationary unless ventilation is needed. They need not be fitted with fire shutters unless the exposure is severe. The windows should be placed high so as to throw light over the top of the cotton bales. Windows may be omitted and light supplied by skylights in the case of the single-story warehouse. If ventilation is to be supplied by the window the opening should be screened, and the sash hinged at the top and controlled by a fusible link and hook. The window has one advantage other than supplying light in that it affords a ready opening through which a hose stream may be discharged effectively. Usually, however, doors supply this need.[1]

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[1] Curtain walls may be of the same material as the bearing wall; or clay wall tile or cement blocks may be used, provided the thickness of the wall is made the same as for brick and in addition provides exterior pilasters having a projection of one-third the wall thickness and spaced at intervals not exceeding eight times the width of the pilaster. For example, a single-story building having a story height of say 13 feet, or not exceeding 18 feet, should provide an exterior wall of 12 inches thickness, which could be of brick, concrete, stone, cement blocks, or clay tile, but if the wall is of cement blocks or clay tile, it should be stiffened and braced on the outside by pilasters having a projection from the wall of 4 inches—that is to say, the thickness of the wall measured through the pilaster should be 4 inches greater than that of the space between pilasters. If the pilasters are 2 feet wide, they should be placed 16 feet apart, while if they are only 1 foot wide they should be placed 8 feet apart—measuring from the center of one pilaster to the center of the next. However, the usual concrete wall column, if extending entirely through the thickness of the wall, is a satisfactory substitute for a pilaster of 3 feet width.

Panels for the exterior wall may be of less thickness than was stated for the division fire wall, panels of reinforced concrete may be only 6 inches thick, while panels of brick and plain concrete may be of 8-inch thickness provided the height of the panel does not exceed 12 feet, though for cement block, clay tile and stone masonry panels, the height should be limited to 10 feet for an 8-inch thickness, additional height necessitating the usual progressive increases in thickness as stated for bearing walls.

Clay tile should be laid with cement-lime mortar and joints three-quarters or 1-inch thick as the mortar serves as a cushion and tends to prevent cracking of the tile from heat. Better work usually will be secured by laying the tile on side rather than on end, as the narrow surface of the tile shell affords but little area for mortar, making it difficult to secure the thick joint desirable. Door openings in the walls should be formed of brick as otherwise the corners of the tile are likely to become badly broken from trucking, thus affording an opportunity for entrance of sparks as well as being unsightly. For walls which do not contain windows, tile offers some advantage in that it can be broken through readily to provide an opening for hose streams.

EXTERIOR DOORS.

Doorways in the exterior wall should be provided in such size and location as may be convenient to the warehouse operatives, and at the same time serve the purposes of the fireman. Convenience in trucking is favored by a wide door, most situations being met advantageously by a door opening 7 feet wide and 6½ feet high. The width, however, may range from 6 feet to 8 feet and the height should not exceed 10 feet. The exterior, or end, wall of the storage compartment ordinarily should have doors at intervals not exceeding 40 or 50 feet apart, measuring from centers of the doors, and usually not less than two doors. The threshold of the doorway should be of cement or iron. It should have a slope outward of 1 inch or more to prevent entrance of blowing rain. The top of the opening should be an arch of the wall material or a lintel of reinforced concrete or steel. For the compress compartment doors may be as numerous as desired and of a width up to 12 feet. It is convenient to have practically the whole wall near the press consist of steel doors arranged to roll up. (See Pl. XIII, Fig. 1.) Certainly the compress compartment should have at least as many and as large doors as should the storage compartment.[2]

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[1] There is another kind of opening that should be provided in the exterior wall. This is known as a "scupper" which consists of an opening in the wall at the floor level for the purpose of discharging water which may accumulate on the floor from any unusual cause, such as the discharge of water from the sprinkler system. Scuppers should be of suitable size and design for the number used to discharge, under 3-inch head of water, 100 gallons per minute for each 500 square feet floor area. Each scupper should have a capacity of not less than 100 gallons per minute under 3-inch head of water, and should meet the other recommendations of the National Fire Protection Association.

[2] An exception to the usual minimum for door openings may be made in case it is not desired to provide doors for ordinary use such as would be true of upper stories not served by platforms on that side. In such instances at least one door should be provided for use of firemen unless the wall is so exposed to other buildings as to make the door a hazard. This type of door should be not less than 4 feet wide, fire-resistive and arranged to swing out. It should be secured by such hardware that it could be locked to the outside but not the inside, the idea being that it should not offer any resistance to firemen shut off on the inside and that firemen seeking to gain access should be able to break the door open without delay. This may be accomplished very simply by a few links of a chain passed through a hole in the door, the inner link being secured by a hook and the outer link by a padlock. Such a door is shown by Plate XVIII, figure 6, and is used for only the upper floors. The landing formed by the projection of the floor slab is very desirable for doors high above the ground.

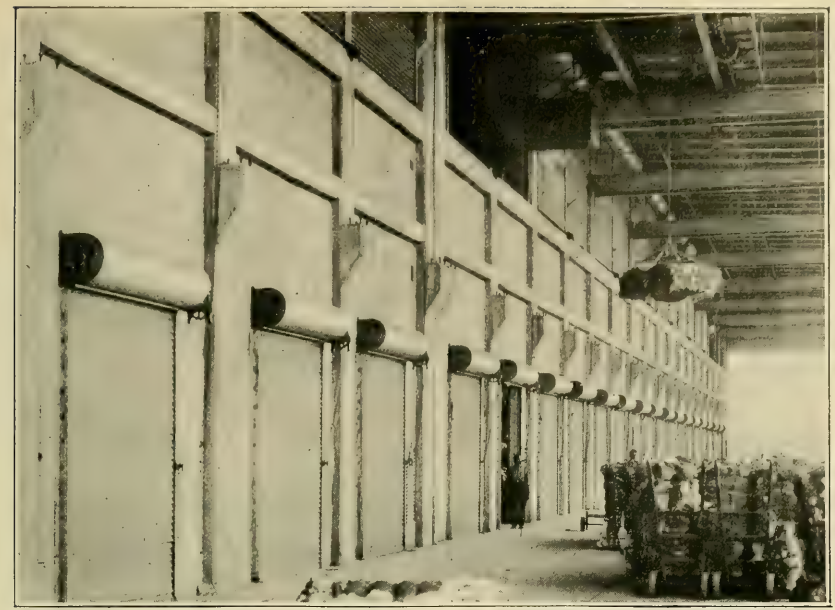


FIG. 1.—ROLL-UP STEEL DOORS ARE EXCELLENT FOR THE COMPRESS COMPARTMENT.

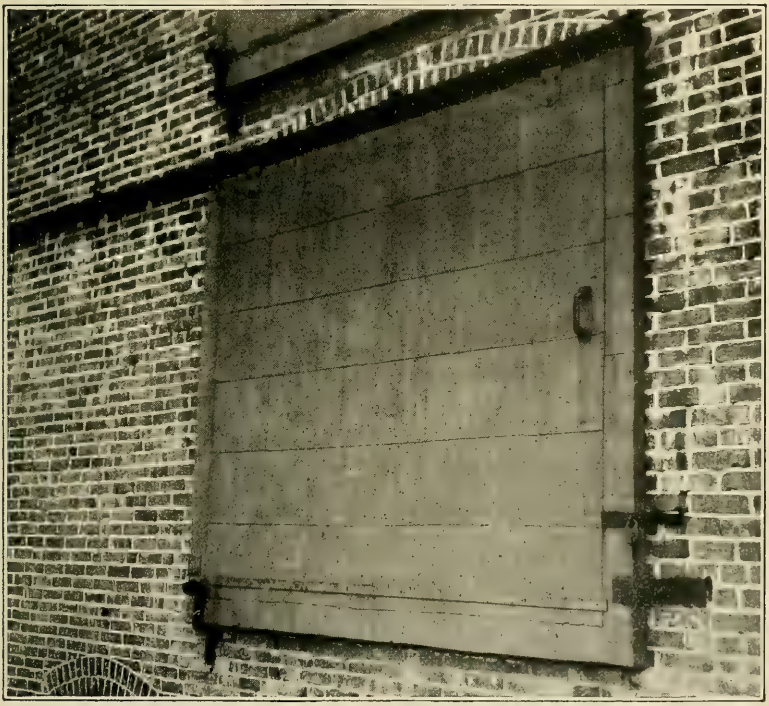


FIG. 2.—A TIN-CLAD DOOR OF A GOOD DESIGN FOR USE IN THE EXTERIOR WALL.

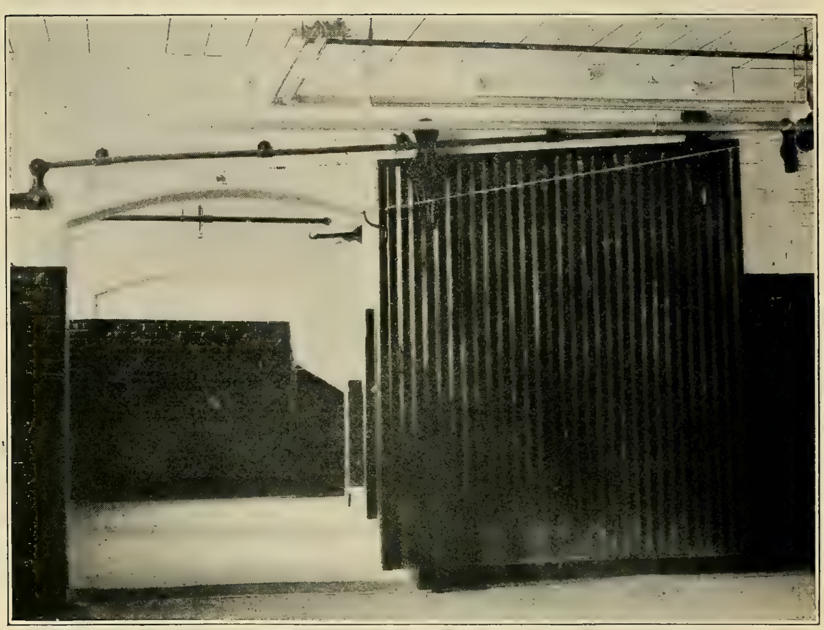


FIG. I.—AUTOMATIC FIRE DOOR MADE OF CORRUGATED STEEL ON A FRAME OF ANGLE IRON.

This door is also suitable for the regular exterior door.

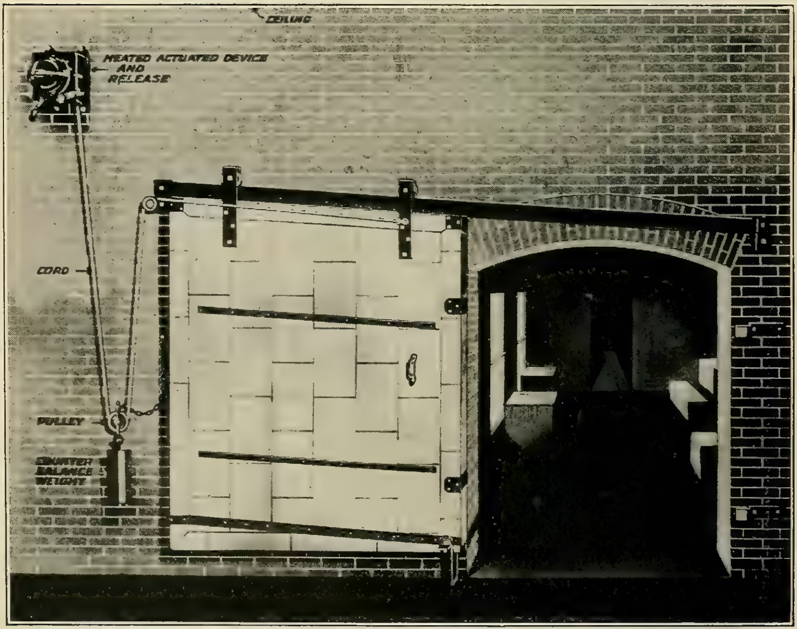


FIG. 2.—FIRE DOOR EQUIPPED WITH A SENSITIVE AUTOMATIC RELEASING DEVICE.

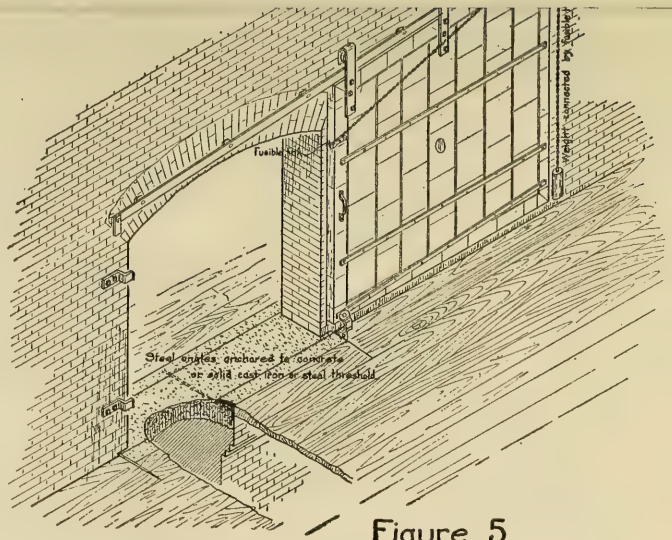

Fusible link
Steel angles anchored to concrete or solid cast iron or steel threshold
Weight connected by fusible link

Figure 5.

AUTOMATIC SLIDING FIRE DOOR INCLINED TRACK.

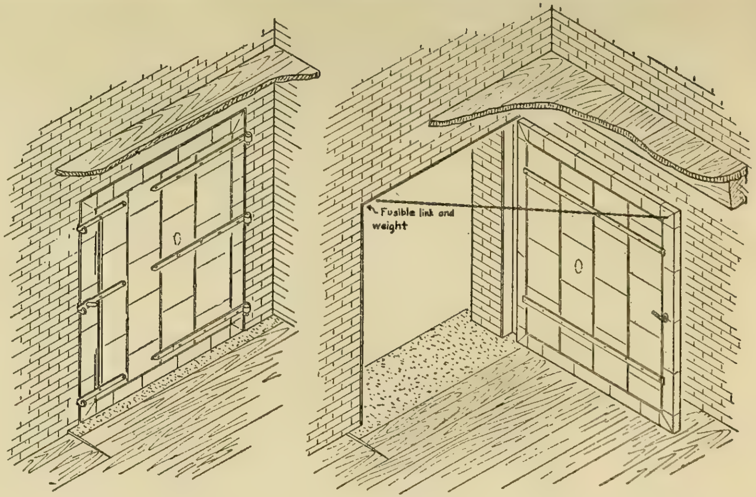
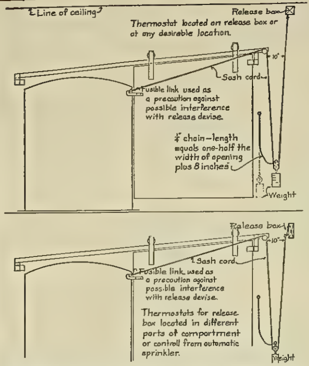


Figure 6.

AUTOMATIC SWING FIRE DOOR: MAY BE ARRANGED FOR SELF CLOSING.


Line of ceiling
Release box
Thermostat located on release box or at any desirable location.
10°
Sash cord
Fusible link used as a precaution against possible interference with release devise.
¼" chain—length equals one-half the width of opening plus 8 inches
Weight
Release box
10°
Sash cord
Fusible link used as a precaution against possible interference with release devise.
Thermostats for release box located in different parts of compartment or controll from automatic sprinkler.
Weight

DIAGRAMS SHOWING METHODS OF INSTALLING SENSITIVE RELEASE BOX-THERMOSTAT CONTROLL.

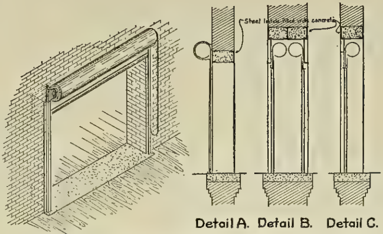


Figure 2. METHODS OF INSTALLATION STEEL ROLLING FIRE DOOR MAY BE AUTOMATIC, HAND-OPERATED, OR BOTH COMBINED.

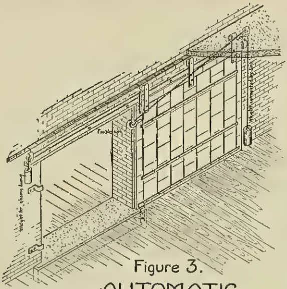


Figure 3. AUTOMATIC SLIDING FIRE DOOR-WEIGHTED.

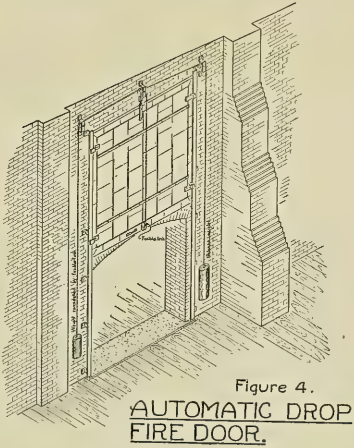


Figure 4. AUTOMATIC DROP FIRE DOOR.

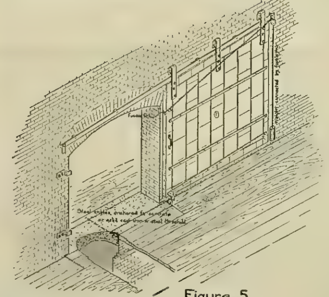


Figure 5. AUTOMATIC SLIDING FIRE DOOR INCLINED TRACK.

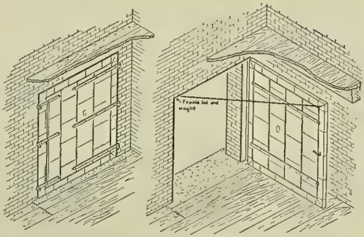


Figure 6. AUTOMATIC SWING FIRE DOOR: MAY BE ARRANGED FOR SELF CLOSING.

Doors in the exterior wall may be of several different types. In most instances the sliding door is to be preferred as it is easy to operate and may be fitted close to the wall. An excellent door of this type is shown in Plate XIII, figure 2. Here the door is composed of three layers of wood covered with tin so as to resist the action of fire from either side. The hardware should be such as to hold the door closed even after long exposure to fire. For this reason all hinges, track supports, and other hardware should be built solidly into the wall. Whether or not doors are locked is a question for the management to decide. Rolling steel doors which slide, or roll up, may be used to good advantage where it is desired to provide openings near together as for a compress. These doors are extremely neat and resist fire well. They have one serious disadvantage for the storage compartment in that they are difficult of operation from the outside, and it is necessary for the person operating them in this way to stand in the opening until the door is entirely raised. The difficulty here in case smoke or flame had to be contended with is apparent. But for the large compress compartment, with its entrance doors of some other type, these doors are excellent. Photographs of installations of these doors are shown in figure 1, Plate XIII. Swinging doors are usually less desirable than sliding doors as the former are somewhat in the way of trucking and are put out of repair more easily.

FIRE DOORS.

Fire doors in the division fire wall should afford high resistance to heat. The construction is similar to those described for the exterior wall, with the addition of requirements for automatic closing in case of fire. There are many types of fire doors which may be purchased ready to install. All of the doors illustrated by Plate XIV are what is termed "tin-clad" (a wood core covered with tin) except that shown in figure 2, this being a steel rolling door which may be installed in the several manners shown. This door is very neat in appearance and affords good protection. Doors of the sliding or hinged type are also made of sheet steel corrugated and riveted to a framework of steel as shown in Plate XV, figure 1. The tin-clad door referred to is an excellent door for an opening in a division fire wall. It should consist of three layers of boards, each not less than thirteen-sixteenths of an inch thick. The tin covering should be applied independently of the use of solder, the joints being securely locked and nailed. There are many details to be followed in the construction to insure the best resistance to fire and positive movement in closing.[1]

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[1] The door can be built locally by a good tin worker and carpenter, or it can be bought ready made. The latter course may be more economical and is nearly

The size of the door should be no greater than necessary and in no case should it exceed 120 square feet in area of opening or 12 feet in width. It is preferable that the door opening be not wider than 10 feet. Doors of large size are not nearly as strong in their resistance to fire as smaller doors. Generally a door should be used on both sides of the wall so as to protect the opening against a long-sustained fire; this also gives greater certainty that at least one of the doors will close.

It is extremely important that a door which has closed from any cause be easy to open from either side, as this is a matter of protection to both life and property. If a door closes during a fire a person may be confined in the fire area, or, on the other hand, persons desiring access to the fire in order to extinguish it may be delayed by their effort to open the door.[2]

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always the more satisfactory provided the purchase is confined to doors approved by the Underwriters' Laboratories. Insurance associations will furnish detailed specifications and explanatory drawings showing the construction of tin-clad doors, but, all too often, these are not followed by the mechanics.

The istallation of all types of fire doors should be such as to insure the holding of the door very securly against the wall and so the hardware (including the track for sliding door) should be extremely heavy and securely applied, since it may be exposed to a long-continued fire. Pieces of hardware attached to doors should be fastened with bolts or rivets extending entirely through the door, while parts applied to the wall should be bolted entirely through it. The door should overlap the wall 4 inches at both sides and top of the opening unless it closes properly into a recessed steel frame securely anchored to the wall. The joint formed at the floor should be close, the door closing upon a steel or iron or concrete threshold extending under it 6 inches.

[2] A variety of fire-door arrangements is shown by Plate XIV. Rolling steel doors with various methods of installation are shown in figure 2, Drawing I. "Detail A" shows an economical method which is satisfactory in most cases.

The sliding fire door is usually to be preferred, as its operation is easy and positive. The usual installation, shown by figure 5, provides an inclined track (having a slope of three-fourths or 1 inch per foot), which causes the door to roll shut by gravity when automatically freed from a restraining weight. This weight (shown to the right of the door) is suspended by a cord which passes over a pulley attached to the track or wall and thence to a bracket secured to the side of the door and projected beyond it and into the opening. The connection between this bracket and the cord is made by a "fusible link" which consists of two thin pieces of metal soldered together with solder, which melts at a temperature of 165° F. The action in case of fire is that this fusible link melts apart, thus disconnecting the restraining weight from the door, which rolls shut by its own weight acting upon the inclined track. The fusible link should be projected into the opening in order that the natural draft of heat through the door may melt the fusible solder as soon as possible.

In situations where the story height does not allow the necessary incline for the track, it may be installed level and the closing action of the door secured by an additional weight, as shown to the left of the opening in figure 3, Plate XIV. This second weight should be connected securely to the door by a substantial sash chain in order that it may hold the door shut during a

Fire doors for protection of openings in a division wall should always be arranged to close automatically in case of fire. The arrangement should be such that the door is held open, against its tendency to close from gravity, by a device which is affected by heat in such manner as to release the door and permit it to close in case of fire. The arrangement may be such that the door normally is closed but may be held open by a special hook designed to release the door should fire occur. All self-closing doors should provide this automatic combination, as otherwise there is danger of the door being purposely obstructed and then overlooked until a serious fire loss has supplied a costly reminder.

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fire. The pulley over which the chain passes must be sufficiently high to insure that the door is entirely closed before the weight reaches the floor. The weights used for holding open either type of sliding door (shown to the right of the doors) should be adjusted to balance the door exactly and so allow it to be closed by hand. The self-closing feature may be added to both of these doors by omitting the weights which hold the door open. When this is done the fusible link should be retained and a hook provided to secure it to the edge of the opening when it is desired to hold the door open. Unless the link and hook are provided, doors should never be self-closing, as they frequently will be obstructed "temporarily" for the movement of goods and then forgotten. If the hook is provided, it will be used as the easiest way of holding the door open, and if the door is, by chance, left open it will still close automatically in case of fire. It should be noted that the hardware for these doors provides a roller at the bottom of the door for holding it close to the wall on one side, while the door is held firmly when closed by the heavy iron bumpers on the other side. These doors show three hangers, the center hanger serving to hold the door against buckling from heat. Two hangers are sufficient for doors not exceeding 6 feet in width, while three hangers are required for wider doors. Goods should never be piled again the door. To guard against this it is sometimes desirable that a substantial slatted guard be provided.

Drop doors, or those vertically sliding, such as is shown by figure 4, Plate XIV, may be used to advantage in case obstructions such as pilasters or buttresses interfere with the horizontally sliding door and where the height of story is sufficient. In the illustration the weight shown on the left is connected by a cord passed through two pulleys to the fusible link placed at the bottom edge of the door, and when the weight is released the door closes. The closing is made gradual by the large counter weight or balance shown on the right. This door may be operated by hand, though it is not opened as readily as the horizontal sliding door, and is particularly difficult to open after the closing has been automatic. Furthermore, it presents some hazard to life if it should drop while a person were passing under it, though this danger is reduced by the large counterweight.

The swinging door shown by figure 6, Plate XIV, is satisfactory though it is better suited to small than large openings It may be arranged to be self-closing or to close automatically, but care should be taken that the fusible link used is placed in position to be reached by drafts of air through the opening. For this door the hardware, unlike that of the sliding or drop doors, must provide substantial latches which will hold the door securely when closed.

RECENT AUTOMATIC DOOR CLOSERS.

Closing devices much more sensitive than the fusible link are now available for use on fire doors. The fusible link requires heating of the solder and surrounding metal to a temperature above 165° F. The length of time required depends on the intensity of the heat at the door which may be placed some distance from the origin of the fire, or subject to conditions which would allow the fire to spread through the opening before closing action of the door. The improved closing devices either provide heat detectors at intervals over the ceiling or provide near the door a single heat detector which responds to a sudden rise of temperature.

As an example of these principles, there is a device which is provided with a heat detector which closes the door to which it is connected when the temperature rises more rapidly than is occasioned by weather or working changes. It is not necessary that the heat reach any fixed temperature, but simply that there be a sudden rise of temperature at the location of the heat detector which may be at the door or a distance from it, or there may be several detectors provided at different places. These detectors may be installed on both sides of the division wall and operate a door on either or both sides, the releasing mechanism usually being on the wall and near the door. The heat detector is connected with the door-releasing mechanism by an air tube and the motive power is supplied by the rate of rise in temperature at the location of any of the detectors. Such a device is extremely sensitive to heat, even though the source of the heat be in a distant part of the compartment. No connections of any kind independent of it are required and no electricity is used.

Another instance of a sensitive door closer is a device based, not as the first on relative change of temperature, but on response to a fixed temperature exceeding 165° F. with means of detecting such temperature placed in different parts of the compartment. This is accomplished by a device which makes an electrical connection when the given temperature is reached. With this system, electrical current may be taken from any constant supply or from a storage battery or both. Unless the installation provides an alarm system which will indicate interruption in supply of current the battery should be used. This device also supplies an automatic fire alarm. It may be connected to the sprinkler system so that when this is called into play all fire doors will be closed.

The new and improved door-closing devices are establishing a good record, but it must be remembered that the simple fusible link has given positive service and a reasonable degree of protection for many years. It is unwise to discard this simple link, but it is desirable that it be supplemented by one of the more sensitive devices if the values of the risk are large and in all cases if the cost is not great. The owner should remember that a division wall loses much of its value if it contains openings not adequately protected and that protection of these openings demands not only that the door resist the action of heat when closed but that it close promptly.

An essential for the satisfactory operation of a fire door is that it be in good order at the time of the fire. Spread of fire through the opening can generally be traced to the fact that the door was out of repair or was obstructed by goods. Therefore doors should be examined and operated by hand frequently and closing devices other than the fusible link should be tested. The examination of the door should be such as to determine whether or not it would close when automatically released, as in case of fire. For example, the sliding door should have its restraining weight lifted gently, care being taken to see that the door moves promptly and closes entirely. Door and track must be unobstructed and rollers must move freely and without binding of the door.

FLOOR DIRECTLY ON EARTH.

The first or ground floor of the compartment (and this is frequently the only floor) may rest directly on the ground, which is decidedly the most economical arrangement in most cases. The material should not be combustible, though treated wood-block paving is not objectionable and is an excellent material for the compress floor. Cement pavement usually gives the best results for such a floor, as it may be trucked over with ease, does not deteriorate with time, and is economical in cost of construction. The chief precaution to be taken in its use is to insure freedom from moisture and consequent damage to the cotton stored directly on the pavement. Where the surface of the floor is a foot or more above the ground on all sides, the site well drained and the soil not excessively wet, no trouble is likely to be experienced, but in less favorable situations special methods must be resorted to in order to prevent the penetration of water. This may be accomplished in almost any situation by proper construction of the floor.[1]

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[1] The cement floor for such locations as do not present serious danger of water seeping through the floor may be laid continuously and without joints except for those that may be caused from a stoppage of work, as from evening until morning. Here the work should be stopped off evenly so as to form a square or right angle, vertical joint with the new work. In cases where there is any danger of water seepage, the floor should be laid in squares with joints between formed every 4 to 6 feet by tar paper, prepared to form a thickness of about one-fourth inch, which permits the floor to expand and contract without forming irregular cracks and at the same time forms a joint which is waterproof.

The pavement preferably should consist of a rough slab of concrete 3 or 4 inches thick, composed of 1 part Portland cement, one-seventh part hydrated

There are many waterproofing compounds on the market which afford various degrees of protection. Those used for concrete usually are designed to be mixed with the water used in preparation of the mortar, whereas some may be used as a brush application to the finished surface. While some of these preparations justify the claim as waterproofing, the prospective purchaser will do well to make thorough inquiry before investing in them.[2]

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lime, 3 parts sand, 6 parts crushed stone (or such amount as may be used with confidence that all voids are thoroughly filled by the mortar—that is, the sand and cement mixture) with water to form a fairly wet mixture. This should be finished on top by a mortar composed of 1 part Portland cement, one-seventh part hydrated lime, 2 parts sand, with water to form a freely working wet mortar. The concrete should be deposited on firmly packed earth and tamped until thoroughly packed with water showing on top. The top-dressing of mortar should be applied as soon as the concrete is packed. Increased resistance to the passage of water from the ground is given by a very dense mixture, such as is secured with a liberal amount of water for mixing and also by the addition of the small quantity of hydrated lime. Sand, for the best results, should be of a mixture of fine and coarse grains, with predominance of the coarse. Under any conditions resistance to the passage of water is increased as the proportion of Portland cement used is greater. (See United States Bureau of Standards, Technical Paper No. 3: Tests of the Absorptive and Permeable Properties of Portland Cement Mortars and Concrete, Together with Tests of Dampproofing and Waterproofing Compounds and Materials, by Rudolph J. Wig and P. H. Bates, 1911.) The top dressing of the richer mixture also supplies a hard, smooth surface which is not readily chipped by truck wheels.

If conditions of the site warrant full protection against water, better protection is secured by interposing between the layer of concrete and the top-dressing, a layer of very pliable tarred roofing felt. The edges of the widths should be fully lapped and cemented by tar and pitch. Where this is done the concrete slab must first be allowed to set and the top-dressing should be 2 or 3 inches thick, while the concrete slab may be reduced to the same thickness. If the top-dressing is too thin and separated from the concrete, it is likely to buckle and crack. The expansion joint of tar paper in this case need extend through the top-dressing only. Still better protection is afforded by a thorough coating of hot tar or tar and pitch applied to the rough slab before the application of the top-dressing, but after the rough slab is dry. In this case the top-dressing need be only 1 inch thick. The expansion joints in this instance should extend through both the rough slab and the top-dressing. The latter method of retarding water is to be preferred, provided care is exercised to see that all parts of the surface are well covered with the tar. Where work is done carelessly the first method usually will be more satisfactory. Either arrangement affords adequate protection. However, for all favorable conditions such precautions are unnecessary.

[2] See United States Bureau of Standards, Technical Paper No. 3: Tests of the Absorptive and Permeable Properties of Portland Cement Mortars and Concrete, Together with Tests of Dampproofing and Waterproofing Compounds and Materials, by Rudolph J. Wig and P. H. Bates, 1911.

A satisfactory substitute for the waterproofing methods described (and a plan which well may be combined with these for unusually trying conditions) is

For most conditions a floor sufficiently dry will be secured by use of the simple concrete pavement first described, provided the proportion of cement stated is not reduced, the sand is not excessively coarse, the stone is of proper size to insure no voids being left open, and reasonable care is exercised in mixing and placing the material.

Floors consisting of a concrete made of a mixture of tar, sand, and crushed stone with thick plank embedded upon this layer and the surface finished with regular hardwood flooring have been used with excellent results. The only objection to this construction is the excessive cost, which is prohibitive for the usual warehouse.

Boards of 2 to 3 inches in thickness may be used laid flat on the ground and nailed to skids 4 inches square bedded in the earth. In this case the timber should be heart pine or oak. Sap pine may be used if air-dried and thoroughly treated with creosote to retard decay. Both of these last forms of floor construction are fairly satisfactory from a fire-hazard standpoint, though they are not as desirable as a strictly non-combustible floor such as is afforded by concrete.

Earth, shell, or cinder floors may be used in some sections of the country where no damage to the cotton from moisture will occur. As a safeguard, however, it usually will be necessary to raise the cotton a few inches above this surface by means of wood strips or stringers. Such floors make trucking extremely difficult and generally should be avoided.

Upper floors of warehouses several stories in height, should be of fire-resistive construction presently to be described. Where there is but one floor and the ground is very rolling, there is a temptation to use heavy frame construction. This should not be done, as such construction reduces the protection against fire very much as far as that compartment is concerned.

Floors of any material and for any conditions, whether there be one floor or several stories, should be constructed with a slight incline from the center of the compartment toward the exterior wall in order that water used in case of fire may drain off readily through wall openings or scuppers provided. This slope should be a total of about

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a system of underdraining of the floor. This may be accomplished by placing 1 foot or more below the floor, a line of open joint field tile, the lines being spaced at intervals of from 25 to 50 feet. The trench in which the tile is laid should be filled with crushed stone, gravel, broken brick or coarse cinders, while still better results are secured when the use of this material is extended to form a layer about 2 inches thick under the floor. The lines of tile should be given sufficient grade or fall to drain off and discharge water finding its way into them.

6 inches in 50 feet, the usual amount for the compartment 100 feet in length between exterior walls. This slope will reduce damage to the cotton and, in the case of elevated floors, will prevent possible overloading from an accumulation of water—such as might result from continued flow of sprinklers.

ROOF AND SELF-SUPPORTING FLOORS.

Designs and materials for fire-resistive roofs and self-supporting floors have been tried in many forms. Many methods of construction used in the early development of fire-resistive construction were needlessly costly and afforded very poor protection. In fact, the simplest and often comparatively inexpensive construction usually has proven the best.[1] This discussion of roof and floor designs will be confined to constructions which is most suitable for the warehouse. For special conditions other types of construction possibly may be suitable.

Reinforced concrete is preeminently suited for the requirements of the cotton warehouse. This material consists of concrete composed of Portland cement, sand, and crushed stone or similar material, so strengthened or reinforced with steel rods as to secure the most economical use of the strength and fire-resistive qualities of both materials.[2]

In this construction the tensile strength, or the capability to withstand a pulling force, is supplied by the steel rods which are protected from the action of fire by the surrounding concrete. The compressive strength, or the capability to withstand a pushing force, is supplied by the concrete. This action of the concrete is sometimes supplemented by additional steel. The value of this construction depends very largely on a proper proportionment and arrangement of the concrete and the steel. A detailed discussion of the engineering phase of the construction is scarcely within the scope of this treatise, though it should be pointed out emphatically that the design should be handled by a competent engineer experienced in this character of work, while the construction should be under careful supervision. The most dangerous construction has been the result of builders having no knowledge of the real principles of engineering involved. The mere judgment of such builders is worthless in this type of construction, even though they may be successful in ordinary frame buildings.

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[1] Valuable information and result of fire tests is contained in a Report on a Test of Floors in the United States, by Ira H. Woolson, E. M., consulting engineer, National Board of Fire Underwriters and Rudolph P. Miller, C. E., superintendent of buildings, New York City.

[2] See U. S. Bureau of Standards, Technologic Paper No. 2: The Strength of Reinforced Concrete Beams; Results of Tests of 333 Beams, by Richard L. Humphrey and Louis H. Losse, 1911.

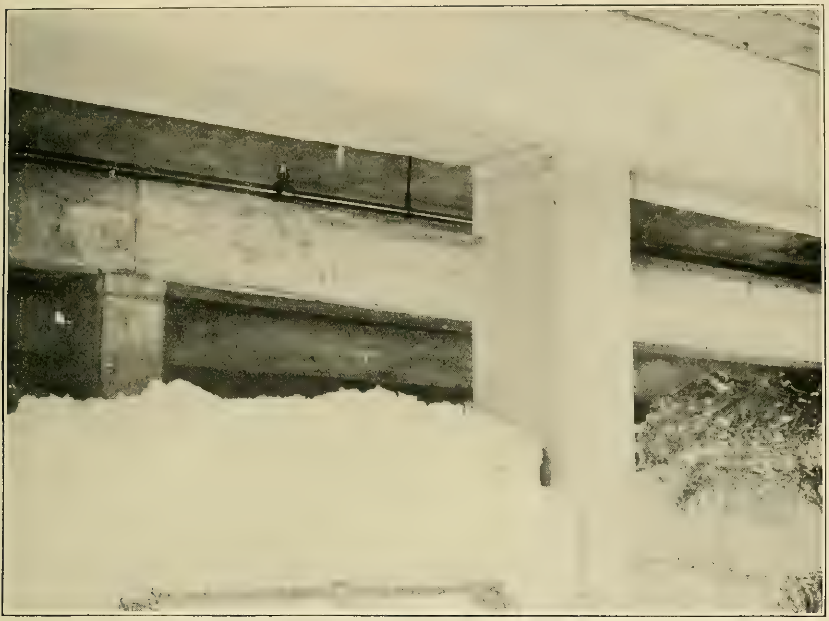

FIG. 1.—CEILING SHOWING A REINFORCED CONCRETE FLOOR ABOVE.

Note the arrangement of sprinkler piping.

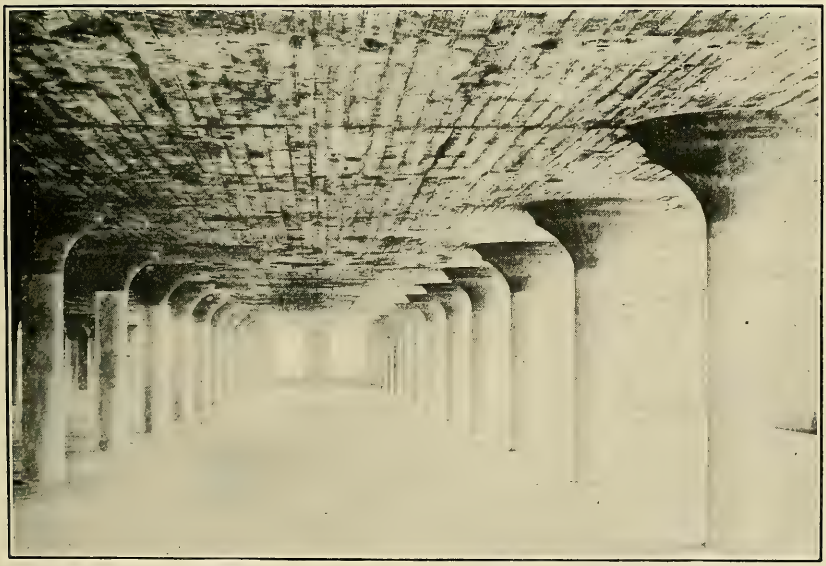

FIG. 2.—INTERIOR VIEW OF A FLAT SLAB DESIGN OF REINFORCED CONCRETE.

Note the unbroken surface of the ceiling so advantageous in the diffusion of light and well adapted to deflection of water from hose stream and sprinklers.

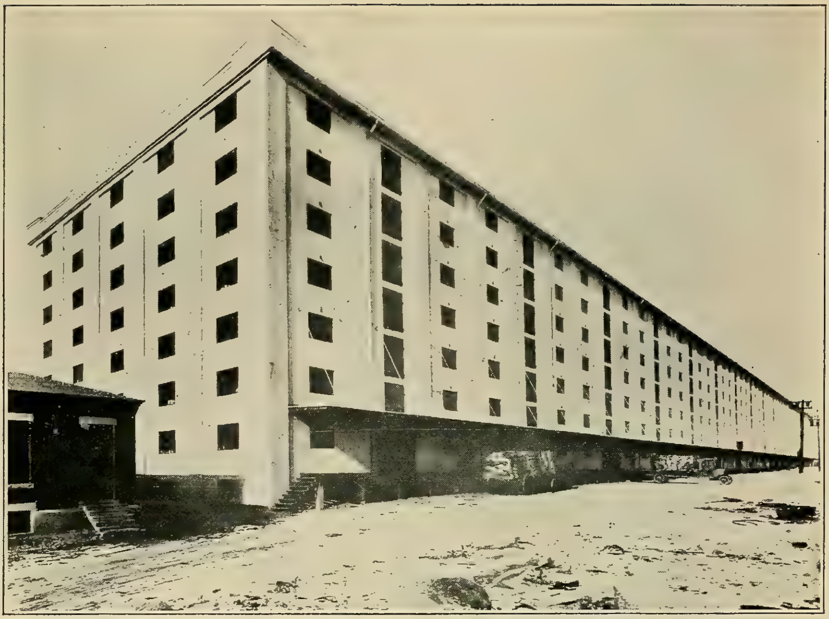

FIG. 1.—VIEW OF A REINFORCED CONCRETE WAREHOUSE OF A DESIGN SUITABLE FOR A GREATLY CONGESTED SITE.

Platforms for each floor should always be provided on one side of such a building and doors on the other side, as shown.

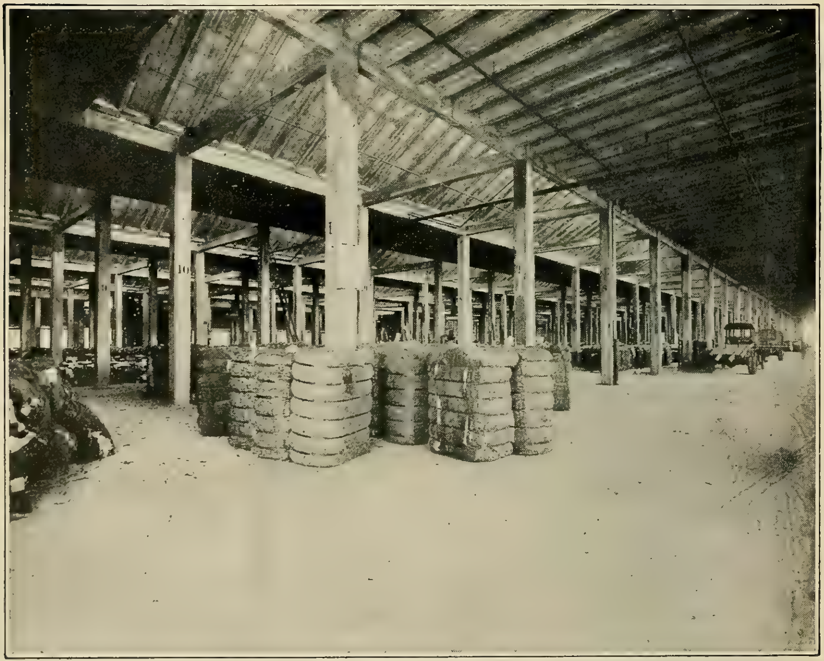

FIG. 2.—INTERIOR OF A REINFORCED CONCRETE COMPRESS COMPARTMENT.

Note the excellent light supplied by the saw-tooth skylights.

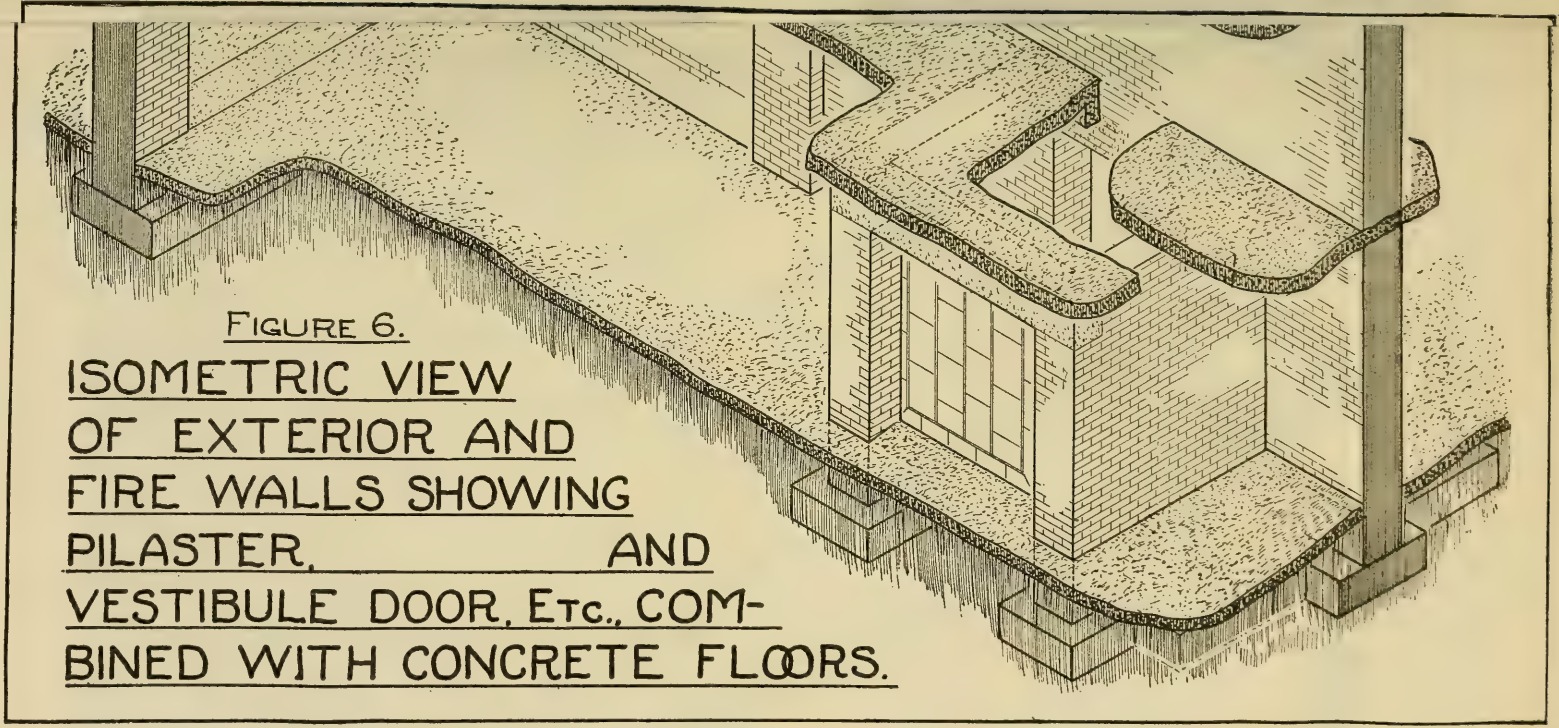

FIGURE 6.

ISOMETRIC VIEW OF EXTERIOR AND FIRE WALLS SHOWING PILASTER, AND VESTIBULE DOOR, ETC., COMBINED WITH CONCRETE FLOORS.

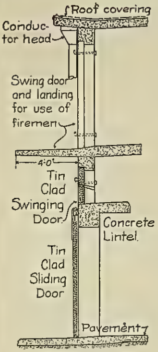

FIGURE 1.
EXTERIOR WALL.

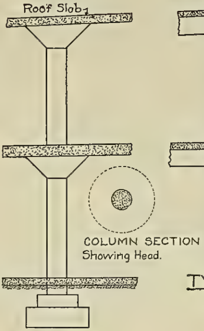

FIGURE 2.
FLAT SLAB FLOOR DESIGN.

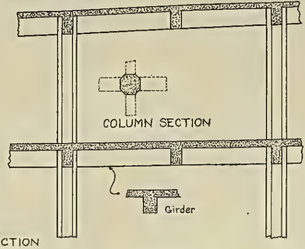

FIGURE 3.

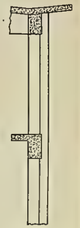

FIGURE 4.

TYPICAL BEAM-SYSTEM DESIGN.

FIGURE 5.
PLAN OF VESTIBULE FOR SLIDING & SWINGING DOORS.

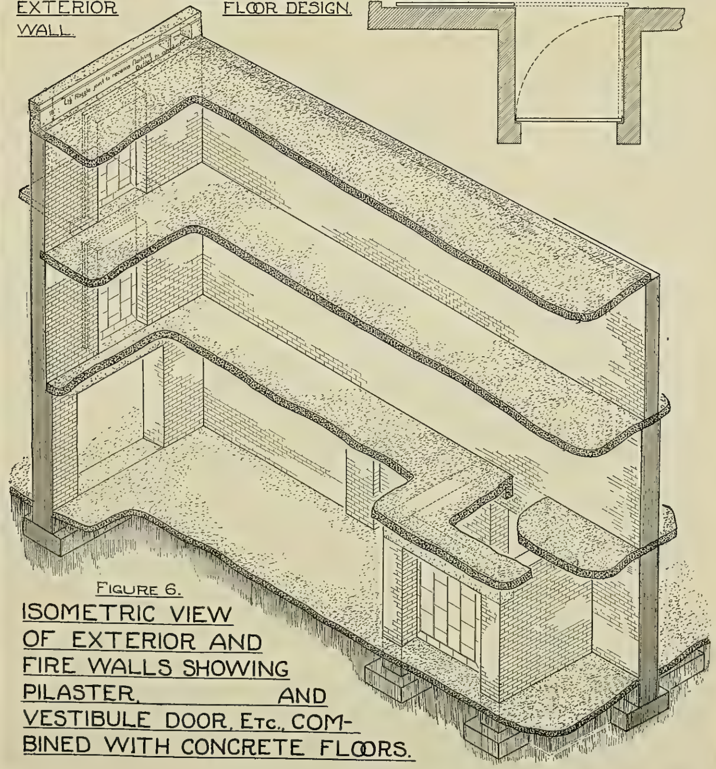

FIGURE 6.
ISOMETRIC VIEW OF EXTERIOR AND FIRE WALLS SHOWING PILASTER, AND VESTIBULE DOOR, ETC., COMBINED WITH CONCRETE FLOORS.

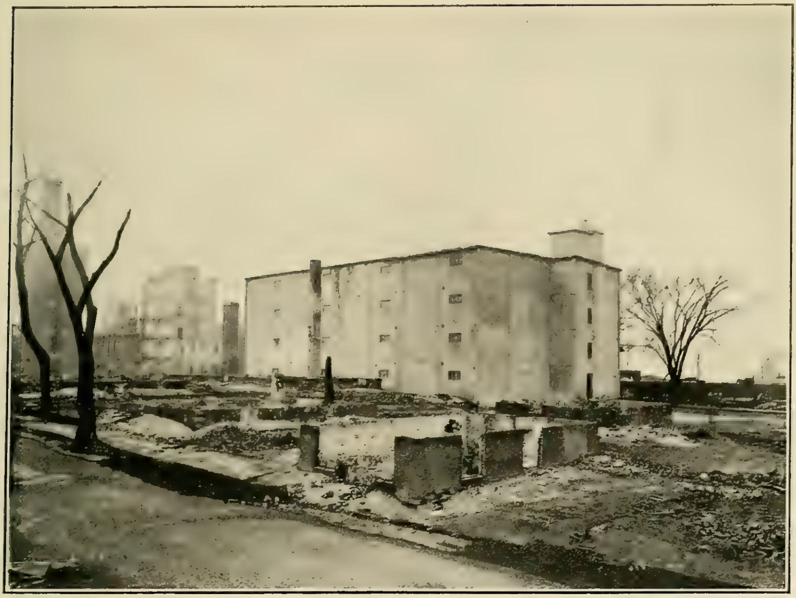

FIG. 1.—WAREHOUSE WHICH SUCCESSFULLY WITHSTOOD SEVERE FIRE TEST.
View shows exterior practically undamaged, although surrounding buildings were destroyed.

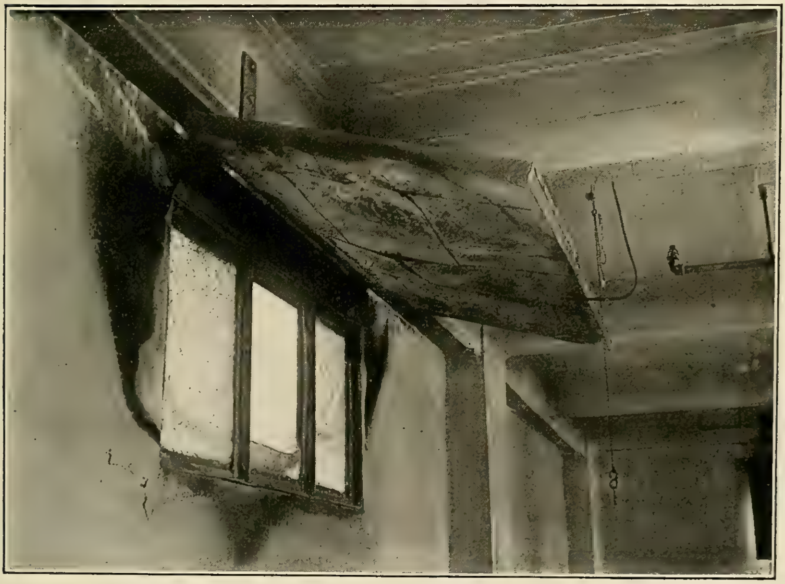

FIG. 2.—INTERIOR VIEW OF ABOVE WAREHOUSE.
Note complete protection afforded by tin-clad fire shutter.

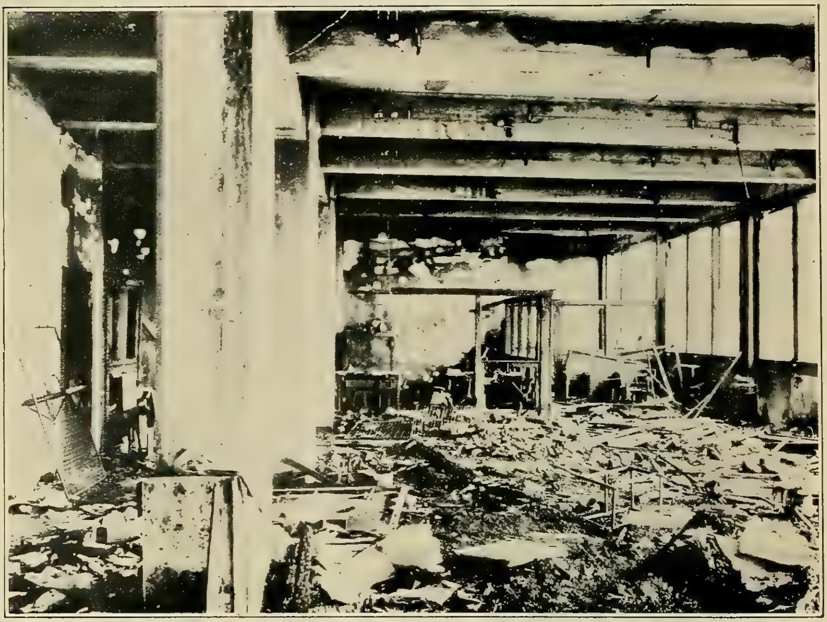

FIG. 1.—INTERIOR OF A REINFORCED CONCRETE BUILDING UNDAMAGED AFTER THE CONTENTS WAS DESTROYED BY FIRE.

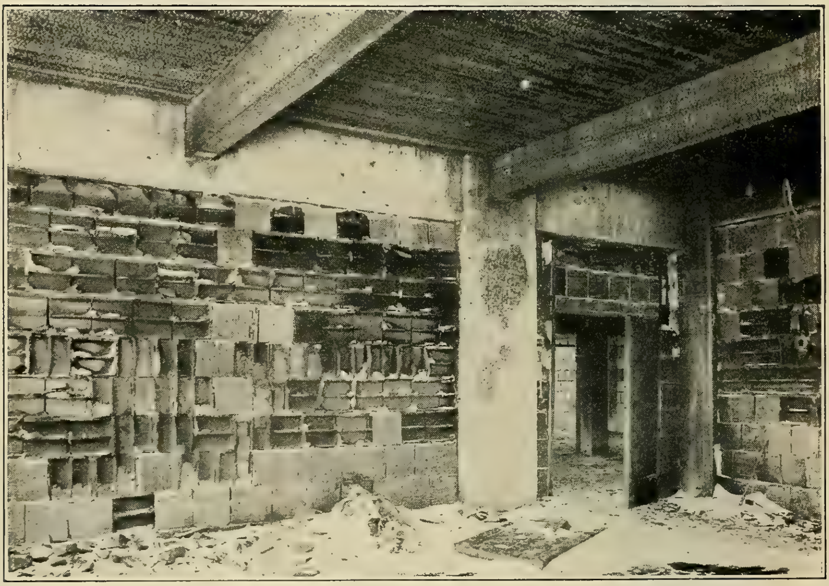

FIG. 2.—A HOLLOW-TILE PANEL WALL AFTER FIRE.

Note that while the tile is badly damaged the ceiling and floor planks are merely charred.

The various types of reinforced concrete floor and roof construction suitable for the warehouse may be considered as the flat slab, consisting of a thick slab supported by columns having large flaring heads, or capitals; the beam system, consisting of beams at intervals supporting relatively thin slabs of concrete between; and a combination of concrete beams and hollow tile in which the slab between main beams is really composed of a series of concrete beams, or joists, separated by a row of hollow clay tile.

The flat-slab system of construction is shown by Plate XVI, figure 2. The exact size and shape of the head of the columns vary with different designs and conditions. The flat ceiling shows freedom from obstructing beams. This permits a minimum height of story, the placing of sprinkler piping close to the ceiling, the most even distribution of light and, in case of fire, the most effective use of water from hose streams. The details of this construction as compared with the beam system is shown by Plate XVIII, figures 2 and 3. The flat slab designs are patented. The proprietors supply plans for their use and either make a charge for this or require the privilege of supplying material for use or actually doing the construction. This type of construction frequently can be used at a material saving over the ordinary beam designs. Unfortunately, there are some limitations to the economical use of flat slab designs for some cotton warehouses. These systems are the most economical when the floor or roof is continuous, the spacing of columns is nearly uniform in both directions, and the load to be carried is heavy.[1]

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[1] These facts may be made more clear by reference to the accompanying plans. The design shown by figure 3 having compartments 40 feet wide with a single line of columns dividing the floor slab into spans—or distances between supports—of 20 feet is admirably suited for a flat slab design provided the division wall is made of reinforced concrete properly designed in relation to the floor or is a panel wall consisting of a concrete frame with panels built of brick or concrete such as was described under discussion of division walls. But if the wall is of any other design, such as brickwork, the flat slab system will not be economical from this standpoint. The spacing of columns in this case is 20 feet from the walls and 16 feet apart, which is satisfactory for the beam construction indicated, though fully as economical results for the flat slab systems would be given by increasing the spacing of 16 feet to 20 feet. The spacing of columns shown is especially economical for the beam design indicated. This plan shows a story height of about 13 feet, which contemplates the storing of cotton two bales high on end, which would result in a floor load of about 100 to 150 pounds per square foot. The flat slab design shows up to good advantage for these and heavier loads, the relative economy of the design being increased as the load becomes heavier. Roofs of this latter design may be used to excellent advantage for the compress compartment, such as is shown by figure 5. Here the spacing of columns 25 feet apart in both directions, with the smooth and unobstructed ceiling, is very desirable.

The ordinary beam system of reinforced concrete design is illustrated by the photograph, Plate XVI, which shows the interior of a compartment similar to those of the warehouse design in figure 2. In this last design the distance between the line of columns and the division wall is 25 feet, the compartment being 50 feet wide. The story height is 8½ feet, which permits the storage of cotton to a height of only one bale on end, and consequently a limitation in load of from 50 to 75 pounds per square foot. This extremely light floor load in combination with the rather long span of 25 feet between the column and wall are distinctly favorable to the beam system of construction.[1]

The combination of clay tile with reinforced concrete has not the advantages for warehouse construction that it has in ordinary domestic building. Its only advantage for the warehouse is that of reducing the amount of concrete and steel required for a given strength of floor or roof. In the case of the most economical design for the warehouse floor there is no advantage in the use of tile.[2]

FAILURE OF POORLY CONSTRUCTED FLOORS AND ROOFS FROM FIRE.

It is interesting to note the degree of success with which the types of construction here described have withstood the tests of fire. A view of a building which successfully withstood one of the

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[1] In this instance the columns are located under alternate beams, while the intervening beam is carried by a cross beam, or girder. The beams are spaced 8 feet apart, which is a very effective spacing with this light load, considering the proportions necessary for both the beam and slab. The best fire resistance for beams is secured when the beam is no thinner than necessary, a good proportion being secured when the breadth, or thickness, of the beam is not more than half the drop, or distance from the bottom of the slab to the bottom of the beam; but in no case should the thickness of the beam be less than 6 inches, while 8 inches is to be preferred as a minimum thickness.

[2] For the roof slab, economy may sometimes be effected by the use of the tile, depending entirely on the local cost of materials. When it is used the blocks should be arranged end to end in a single row and with a space between rows of not less than 6 inches for the concrete joists, which are cast between. The whole top surface should be troweled over with cement mortar after casting to receive the roofing material. Even with the best of workmanship this construction is not as good as solid concrete, and the chances of poor workmanship are much greater than with the latter. Only a substantial saving in cost would justify a departure from the solid concrete for this particular character of building. The semi-porous clay tile is best for this use.

For all of these designs, columns should receive very careful attention. They may be round, octagonal, or square. The round is the best shape, but usually requires the use of metal forms. The octagonal shape is practically as good and is readily secured by use of wooden forms. The square column, most severe fires—the conflagration of Salem, Mass.—is shown in Plate XIX, figure 1. This view shows the exterior of the building practically undamaged after the surrounding buildings had been destroyed. The interior view (fig. 2 of the same plate) shows the complete protection afforded by the tin-clad fire shutter. The interior of another building which withstood the test, though the contents were entirely consumed, is shown in Plate XX, figure 1. Some idea of the effect of fire on hollow clay tile may be gained by an examination of Plate XX, figure 2. Here the fire wall is of the panel-wall type previously described, the tile panels being carried in a frame of reinforced concrete. The timber and plank floors of this building were only slightly charred by the fire which shattered the tile as illustrated.

SOME DETAILS OF CONSTRUCTION.

Emphasis should be given to the previous statement that the designing should be done by a competent engineer. Reliable engineering service is frequently supplied by proprietors of the patented systems, but it is best to have the services of a disinterested engineer who is familiar with the character and cost of the local materials to be used.[1]

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while entirely satisfactory for exterior use, as for platforms, is not the most desirable for use inside as the corners are readily damaged by severe fire or broken by trucks.

While concrete properly reinforced with steel is the best material for fire-resistance floors and roofs, it is true that there have been cases of poor design and workmanship which failed utterly, and there are isolated instances of substantial reinforced concrete structures being damaged by extremely severe and prolonged fire. These fires have shown that concrete should be cast solidly in place in such manner as to make the building, or large sections of it, one solid whole, or monolithic, structure. These tests have further demonstrated the necessity of so placing the steel that it will be well protected from heat by the surrounding concrete. Such observations have indicated that concrete floor slabs should have a protecting thickness of concrete for the steel of 1 inch, while this thickness should be 1½ inch for walls and beams and 2 inches for very heavy beams, or girders, and columns. If such protection is not provided, a severe fire is likely to result in the steel reinforcement becoming so heated as to stretch, causing serious damage to the structure.

Floors may extend through division fire walls provided the mechanical design is such as to make the floor on either side independently self-sustaining in case the floor on the other side of the wall is destroyed. The same construction may be applied to the roof slab. This involves some modification in arrangement of reinforcement, and in some cases additional material. These stresses which would arise only in an emergency may be computed on the basis of the elastic limit of the materials rather than with reference to the usual allowable stresses which should be used in computing the normal working load.

[1] Materials for concrete permit of wide variation. The proportions for concrete reinforced should usually be 1 part Portland cement, 2 parts sand, 4 parts stone, and water as required. The stone should be in small pieces

Reinforcement should consist of steel of medium hardness and for general use should be in the form of bars or rods, as they are adaptable alike for walls, columns, beams, and slabs. These bars may be of any suitable shape, of which there are a great variety on the market. The plain, round or square bars are entirely satisfactory for all ordinary sizes. Many companies make a specialty of supplying steel for this use; the rods may be had cut to the proper length and bent to the exact shape desired. Usually it is best to use regular stock lengths and do the bending locally. A very simple bending machine for hand operation may be had for this work. Reinforcement for use in the slab may consist in whole or in part of woven-wire reinforcing

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not over 2 inches in diameter, and preferably should be of varying sizes, ranging from 1½ inches down. It may consist of hard stone, such as trap rock, granite, limestone, and aggregates which are hard and do not decompose when subjected to severe heat. (The U. S. Bureau of Standards may supply reports, at a very small charge, on materials submitted.) The sand should be clean and free from loam, clay, or organic matter. The grains should be fairly coarse or a mixture of fine and coarse with the coarse grains predominating. The Portland cement should be of a good quality. While analytic tests have been fixed as a required standard (see U. S. Bureau of Standards Circular No. 33, United States Government Specification for Portland Cement, 1912; also Standard Test Specifications for Portland Cement recommended by the American Society for Testing Materials), it is usually a safe policy to use a brand of cement which has been on the market and in satisfactory use for five years and is made by a reliable company. Water for mixing should be free from alkali or injurious salts in damaging qualities. (See U. S. Bureau of Standards Bulletin No. 12: Action of the Salts in Alkali Water and Sea Water on Cement.)

Slag from blast furnaces, if burned free from coal, may be used as the coarse aggregate for concrete. It makes a concrete which is light, fairly strong, and withstands fire well. However, there are but few localities where slag is available.

Crushed terra cotta, tile, or brick are good substitutes for crushed stone for concrete, provided the clay material is hard-burned and used properly. After crushing, the dust should be screened out and the crushed brick should be wet thoroughly before mixing, for if the material is used dry it will absorb too rapidly the water used in mixing the concrete. Care should be exercised to see that brick used are hard and well-burned and that they are free from mortar; otherwise the finished concrete will be unreliable in strength.

Gravel should not be used for concrete work which may be subjected to fire, as such use has been found exceedingly dangerous. The use of quartz gravel in the reinforced concrete of a warehouse at Far Rockaway, N. Y., caused serious damage from a fire of comparatively short duration. A detailed report of this fire, written by Mr. Ira H. Woolson, may be had from the National Board of Fire Underwriters, New York City. A valuable test of gravel as compared with other stone for concrete has been made by the Bureau of Standards and the results have been recorded in an illuminating way by Mr. Walter A. Hull. (See Proceedings American Concrete Institute, Vol. XIV, 1918.) There is no objection to gravel, however, for concrete paving and for footings of the foundation.

materials which frequently can be used to better advantage and are more easily kept in place while the concrete is being deposited. Punched sheet steel also may be used provided the metal is not too thin.[1]

Forms for reinforced concrete may be used with maximum economy in construction of the warehouse. The uniformity of requirements with the consequent duplication of units, or compartments, makes possible a very high degree of standardization in form work with the result that forms can be used over and over again. The usual construction is with forms built of wood, though forms of steel are coming into use. Steel forms for columns, particularly those with flaring heads used for flat-slab construction, are desirable. Steel forms are also in use for wall construction. For floor or roof slab and beams, wooden forms generally are used and fulfill every requirement. These should be constructed in units of such size as to permit easy movement for additional use. The slab forms should be made of ordinary matched flooring; the same material may be used for beams and columns, though for this use material 1½ or 2 inches thick and closely jointed is to be preferred. It is of primary importance that all form construction be very rigid and of sufficient strength to support the heavy wet concrete without distortion, as any disturbance of concrete during setting is a serious impairment to its strength.

The floor slab should be finished with 1 inch of top dressing mortar composed of the same material described for finishing the paved floor. In this case the hydrated lime may be omitted, if desired. The rough slab should be wet thoroughly before this mortar is applied to insure a good bond between the two. Only the rough slab thickness should be considered in calculating the strength of the floor or roof.[2]

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[1] Reinforcement should not be painted, as this renders less effective the bond or "grip" of the surrounding concrete upon it. This objection also holds good in regard to excessively rusty metal. Particular caution should be exercised against the use of badly rusted wire or punched steel, as here the amount of surface, as compared with the sectional area is large, and hence a definite penetration of rust gives a correspondingly greater reduction of strength than would be true of the larger rods.

Mixing of concrete should be done very thoroughly, the best results being obtained by the use of a machine of the type known as the "batch mixer." Sand and cement should be mixed dry before the water is added. Mixing should not be done in freezing weather. The concrete should be placed as fast as it is mixed, and should be tamped thoroughly to secure a dense mass free from voids. Reinforcement should be placed and inspected in advance and should be well secured against displacement.

[2] The roof slab should be smoothed off carefully as casting is done, or else there should be added a top dressing of 1 part Portland cement to 4 or 5

ROOFING MATERIAL.

Roof-covering material for the roof slab should be suitable for application without nails and for application by roofing cement directly to the surface. The material should be enduring under exposure to the weather and not inflammable. Two types of roofing material which may be mentioned as illustrating these qualities and being well suited to the desirable flat roof of the warehouse are "tar and gravel" and asbestos composition built-up roofings. Materials for tar and gravel roofing are manufactured by a number of concerns, some of which, at a small charge, will supply some supervision of the work and inspection service at intervals with a guarantee against leakage for 20 years. Where such an arrangement is not made, the owner should require the roofing contractor to guarantee the roof against leakage for a period of 10 years. This roof is probably the most economical for the warehouse. Its use is limited to comparatively flat surfaces, the slope of which in no case should exceed 3 inches per foot and may be practically flat. The best slope for the warehouse roof from every standpoint is one-half inch per foot.[3]

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parts of sand in order to provide an even surface for application of the roofing material. In some very dry climates it should be satisfactory to depend on the concrete slab to afford protection from water, but for ordinary conditions this is not desirable, as it is difficult to prevent such cracks and openings as will result from contraction and expansion and from poor workmanship. Great care necessary to overcome this would usually be more expensive than the use of roofing material.

[3] The tar and gravel roofing is composed of several layers, preferably five, of roofing felt (a fibrous material formed into a paper-like sheet by the use of a tar or bituminous binder), well covered on the top surface with tar pitch applied hot and overlaid with gravel. The first layer of paper should be cemented to the concrete surface of the roof by hot tar pitch while successive layers should be bound together in a similar manner. The final surface of tar-pitch mixture poured on roof binds the gravel covering to the surface, the gravel being spread in place while the tar is hot. The gravel serves as a protection to the tar against the heat of the sun. The gravel, slag, or crushed stone should be washed free from dirt and should be screened to a fairly uniform size, which should be from one-fourth to five-eighths inch in diameter. The value of such a roof depends very largely upon the reliability of the workman, as this is a case where workmanship counts as much as material.

Asbestos composition roofings also are suitable for cementing directly to the roof slab. They are laid in several cemented plies similar to the method for tar and gravel roof, but no protecting gravel covering is required. The slope of the roof may be flat or as great as desired. Here also the personal element of workmanship is a vital factor, some manufacturers allowing their product to be used only where it is to be applied by roofers licensed or employed by them. Such roofing is ordinarily more expensive than the tar and gravel roofing. The asbestos roofing also may be purchased under a guarantee for service.

ROOF OPENINGS—VENTILATORS AND SKYLIGHTS.

Openings in the roof such as are needed for ventilators and skylights are permissible, though generally it is desirable that the sizes should not exceed the minimum necessary. Ventilators should be of metal, so designed as to be proof against the entrance of sparks from the outside. A convenient size is the 12-inch or 18-inch diameter round type of ventilator, of which there are a number of styles on the market. The revolving cowl ventilators should be used for the compress compartment. They discharge an enormous amount of air, as they are not dependent on merely difference in temperature within and without but are actuated also by a slight breeze. Either type of ventilator may be combined with the skylight. Ventilation may be given by the arrangement of one or more sides of the skylight, as louvers, or with a slatted construction. In such case the slats should be made of sheet metal rigidly set at an angle of 45° or more with the horizontal and overlapping. Where ventilators of any type do not provide satisfactory baffles to prevent the entrance of sparks, the opening should have a screen of No. 16 wire woven and galvanized, with a mesh of not over three-eighths inch.

The skylight in any case should be of metal frame, glazed with one-quarter-inch wire glass—that is, glass having woven wire made in it. Such glass will retard the passage of fire for a considerable time, whereas the ordinary glass is soon shattered by the heat. Moreover, wire glass is less easily broken out and so affords better protection for the opening. The glass should be set securely in the metal frame and made water-tight.

Fire shutters for skylights and ventilators are not required, as the chief hazard is assumed as from within. The resistance to fire afforded by the arrangements described is sufficient to prevent a rapid circulation of air and consequent rapid growth of fire, thus affording the best opportunity for extinguishment by the automatic sprinkler or hand appliances. Should these fail, however, the use of hose streams will be facilitated by the opening of the skylight, thus creating a draft and relieving the doors to some extent from projecting flame. They also provide an opening for the injection of hose streams.[1]

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[1] Excellent skylight frames can be made of galvanized sheet iron of No. 24 United States gauge. Both the monitor and saw-tooth types of skylight are well adapted for the compress section, while the smaller metal frame skylight is suitable for the storage compartment. Practical use generally demands that the large glass sections of the saw-tooth or monitor skylight of the compress compartment be arranged to open at times, though when this is done the arrangement should be such as to permit the opening to be protected by a wire screen as described for the ventilator. The skylight

PLATFORMS.

Platforms connected with the warehouse should be of concrete for the pavement directly on the ground, or reinforced concrete for platforms above the ground. The platform for the first floor would consist, in nearly all cases, of a paved area which would either rest directly on the ground or on an earth fill inclosed by a retaining wall. Such an arrangement is shown by the drawings in figure 1. In some cases the first-floor platform may be constructed more economically of reinforced concrete. For floor above the ground floor, platforms always should be constructed of reinforced concrete, the details of construction being the same as described for such floors. Illustrations for such platforms are shown by drawings in figures 2 and 3. The width of platforms is a variable factor, though 10 feet usually should be accepted as a minimum, as this gives convenient room for the passage of the ordinary hand trucks. Platforms used for loading or unloading cotton from cars should be 20 feet wide, if possible, since this will allow the placing of cotton in quantity on the outer half of the platform, and yet provide a clear space of 10 feet between such pile of cotton and the warehouse wall. In the design of the platforms to be used in loading cars, no columns should be placed at the edge of the platforms, otherwise freight cars must be "placed" accurately to avoid having a column block the car door. Good platform construction is shown by the plan for a compress compartment in figure 6 and the storage warehouse plan in figure 2. The practice of roofing platforms, while very convenient, is an expense which usually can not be justified except in the case of the compress compartment and such adjacent storage compartments as are used in conjunction with it. Here platforms usually should be covered.

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for the storage compartment should be stationary, so as to be closed at all times. Skylights for the storage compartment should be only of such size and number as is necessary for convenient handling of cotton and reading of tags. A size of 4 to 6 feet square is very convenient, while the size usually should not exceed 64 square feet. The compress section, however, requires considerably more light and ventilation, and the different conditions do not permit of a fixed size for these openings.

The single panes of glass used for these skylights should be of such size as not to exceed an area of 1,728 square inches or a width of 18 inches, the thickness of the glass being at least one-quarter inch. This limit of width is desirable for all glass; that used in a nearly vertical position (making 80° or more with the horizontal), if subject to an exterior exposure, should be restricted further to 720 square inches area and 48 inches for the greatest dimension. An example of this last requirement is that of monitors near together on a fire-resistive roof and communicating with separate compartments. However, this condition seldom obtains and the first limit stated is generally satisfactory.

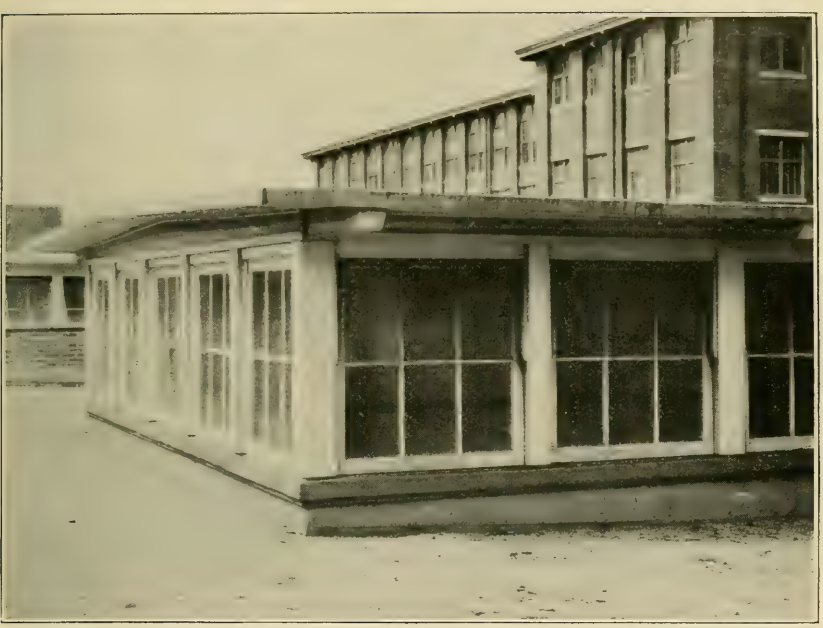


FIG. 1.—A MONITOR WHICH SERVES AS AN EXCELLENT SOURCE OF LIGHT AND VENTILATION FOR THE COMPRESS COMPARTMENT.

It should not be used within 50 feet of fire walls except when the monitor is of fire-resistive construction.

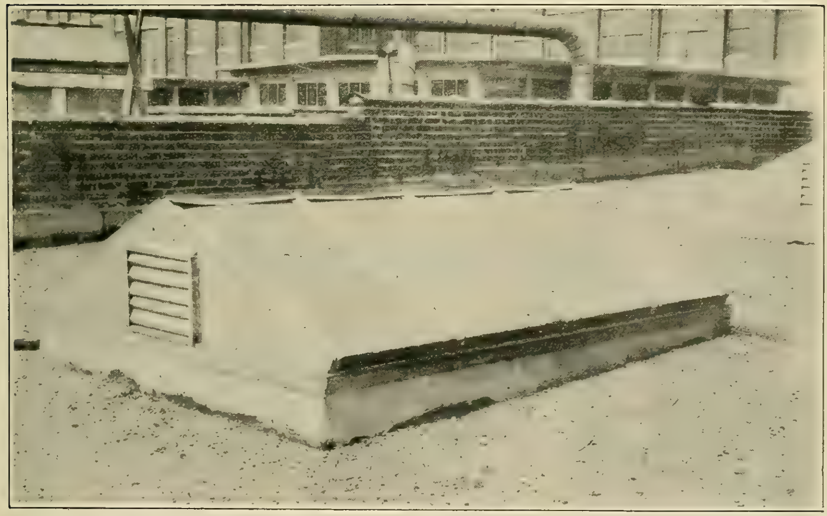


FIG. 2.—THE METAL FRAME SKYLIGHT AFFORDS ONE OF THE BEST MEANS OF LIGHTING THE STORAGE COMPARTMENT.

Note the ventilation provided in the end.

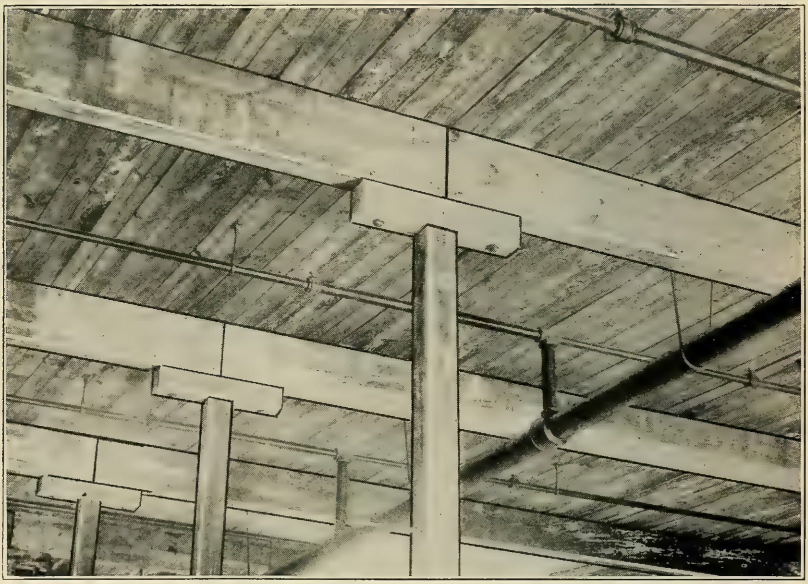


FIG. 1.—INTERIOR SHOWING SLOW-BURNING ROOF CONSTRUCTION OF A CHEAP BUT SATISFACTORY TYPE.

Note the simple method of framing post and timbers.

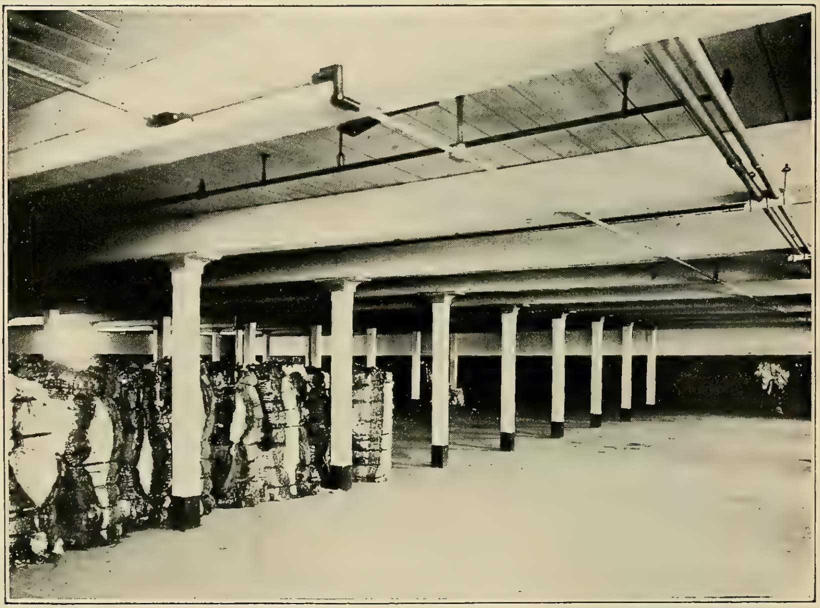


FIG. 2.—WELL-FINISHED INTERIOR OF SLOW-BURNING CONSTRUCTION.

The cast-iron post cap affords an excellent connection for timbers.

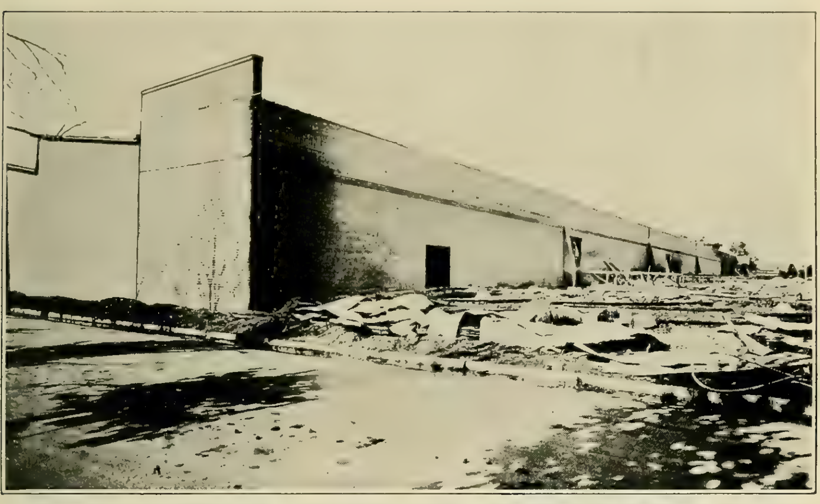


FIG. I.—A DIVISION FIRE WALL WHICH CHECKED THE SPREAD OF A FIRE THAT CONSUMED A COMPARTMENT FILLED WITH COTTON.

Note that the timbers supported by the corbel fell without damage to the wall and that the buttresses prevented buckling of the wall from heat.

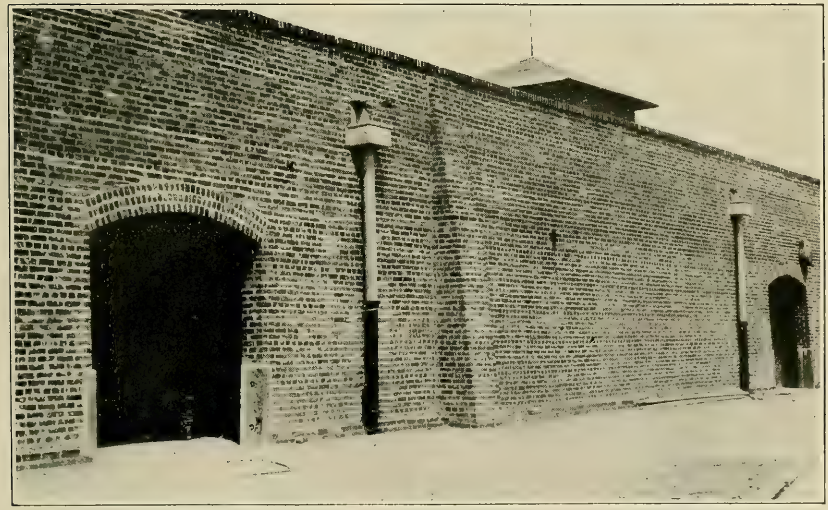
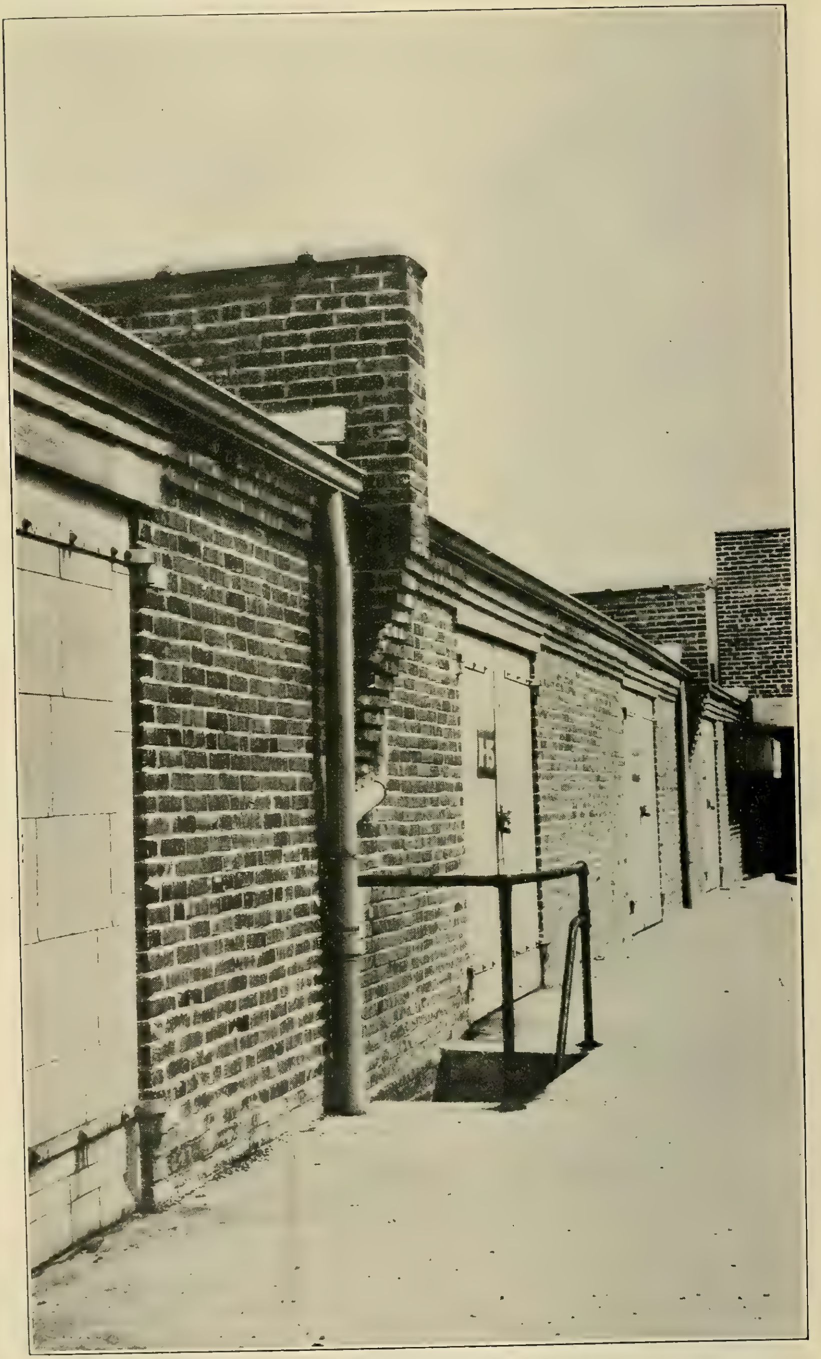


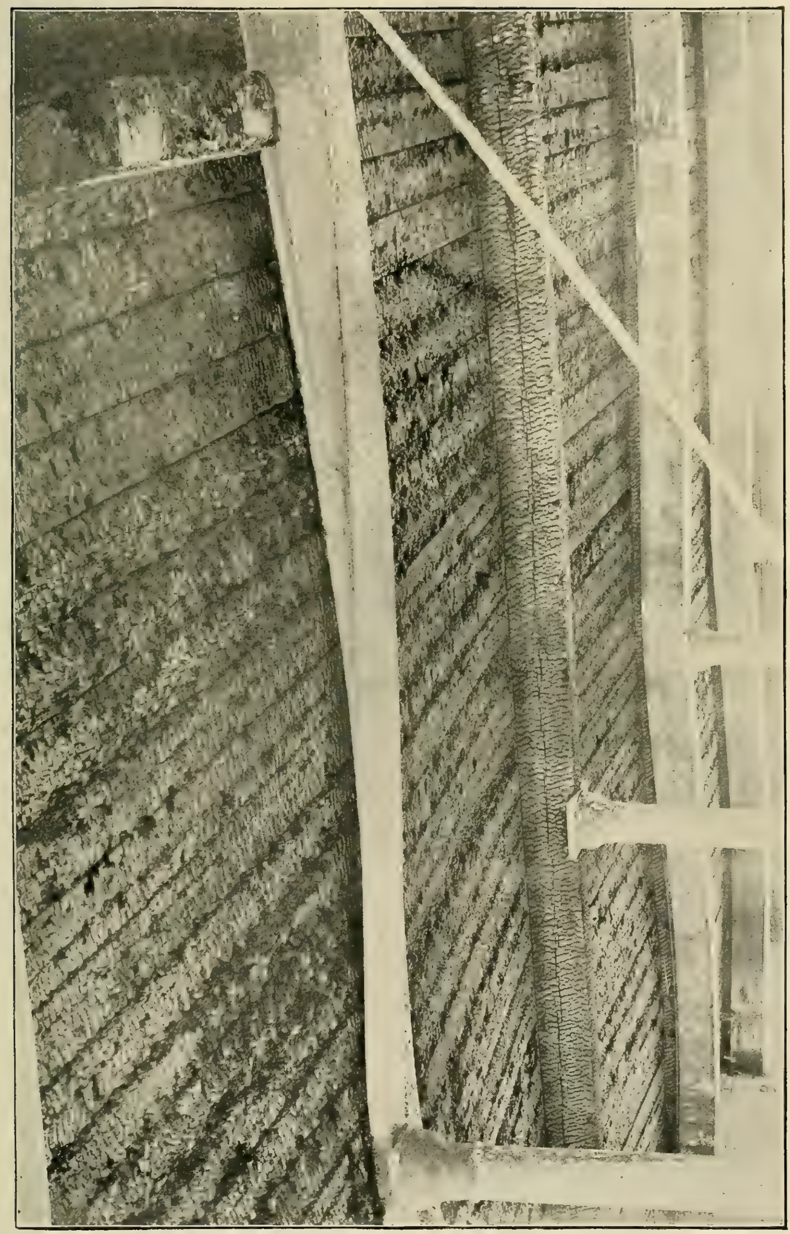
FIG. 2.—A LONG WALL BRACED BY BUTTRESSES AGAINST BUCKLING FROM FIRE.

Other notable features are the conductor head with scupper above, the lower end of the metal conductor discharging into cast-iron pipe, and the cast-iron door guards.



A GOOD METHOD OF FINISHING A WALL AND CORNICE UNLESS THE WALL IS PARAPETED.

PLATE XXV.



Interior View of Combination Steel and Timber Construction After Fire.

Timbers charred but slightly damaged, while the steel beams were twisted and caused to sag by the heat and rendered worthless.

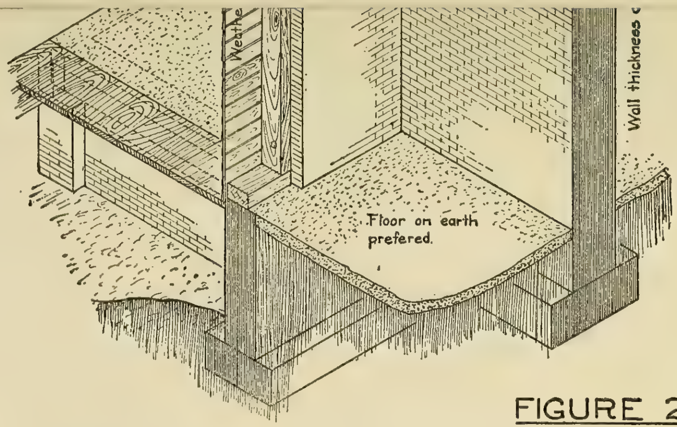


FIGURE 2.

VIEW OF FIRE WALL "T" WOOD END WALL, PAVED BREAK IN WOOD PLATFORM, AND DWARF WALLS FOR SEMI-SLOW-BURNING CONSTRUCTION.

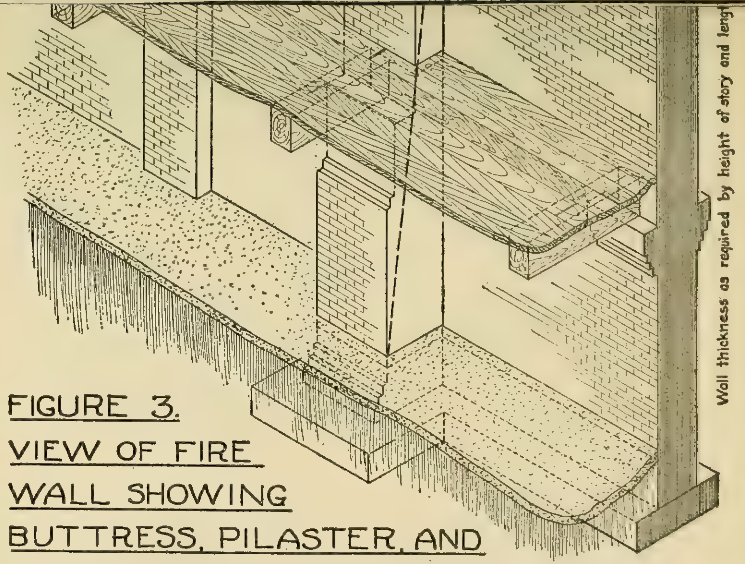
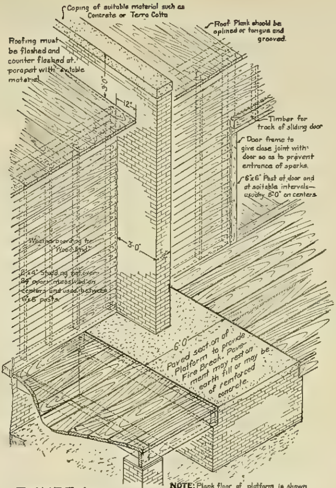


FIGURE 3.

VIEW OF FIRE WALL SHOWING BUTTRESS, PILASTER, AND CORBEL FOR TIMBER SUPPORT.

DETAILS OF FIRE BREAKS FOR SLOW-BURNING CONSTRUCTION.


Coping of suitable material such as Concrete or Terra Cotta
Roof Plank should be splined or tongue and grooved.
Roofing must be flashed and counter flashed at parapet with suitable material
3'-0"
12"
Timber for track of sliding door
Door frame to give close joint with door so as to prevent entrance of sparks.
6"x6" Post at door and at suitable intervals—usually 6'-0" on centers.
Weatherboarding for Wood End
3'-0"
2"x4" Studding not over 24" apart, measured on centers and used between 6"x6" posts.
6'-0"
Paved section of Platform to provide Fire Break. Pavement may rest on earth fill or may be of reinforced concrete.

NOTE: Plank floor of platform is shown only to illustrate "break". Concrete is best.

FIGURE 1.
VIEW OF FIRE WALL EXTENSION WITH DWARF WALL THRU THE WOOD PLATFORM.

NOTE: Planking and framing should be proportioned to the loads required and stresses allowed for the material used, but should not in any case fall below the minimum of 2½" for Roof Plank and 3" for Floor Plank thickness; 6" breadth of beam; 8" for least dimension of post and bolster, except that wall posts used as studding may be 6"x6"

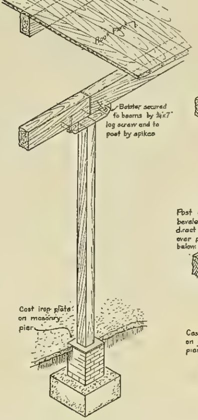

Roof Plank
Bolster secured to beams by ¾"x7" log screw and to post by spikes
Cast iron plate on masonry pier

FIGURE 4.
VIEW OF POST SINGLE STORY.

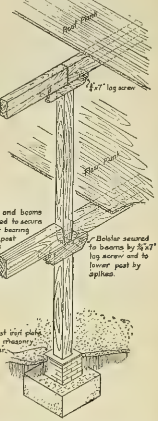

Roof Plank
¾"x7" log screw
Floor Plank
Post and beams beveled to secure direct bearing over post below
Bolster secured to beams by ¾"x7" log screw and to lower post by spikes.
Cast iron plate on masonry pier

FIGURE 5.
VIEW OF POSTS MULTI-STORY.

FRAMING, SLOW-BURNING.

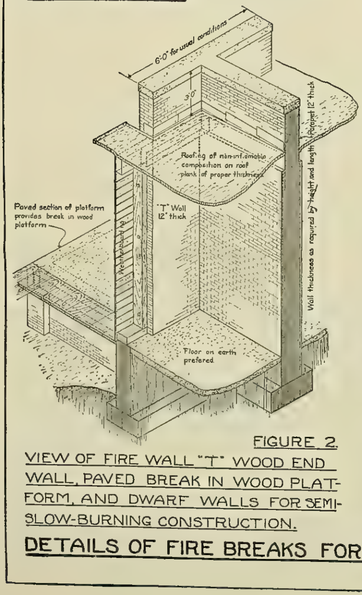

6'-0" for usual conditions
3'-0"
Parapet 12" thick
Roofing of non-inflammable composition on roof plank of proper thickness
Paved section of platform provides break in wood platform
"T" Wall 12" thick
Weatherboarding
Wall thickness as required by height and length
Floor on earth prefered

FIGURE 2.
VIEW OF FIRE WALL "T" WOOD END WALL, PAVED BREAK IN WOOD PLATFORM, AND DWARF WALLS FOR SEMI-SLOW-BURNING CONSTRUCTION.

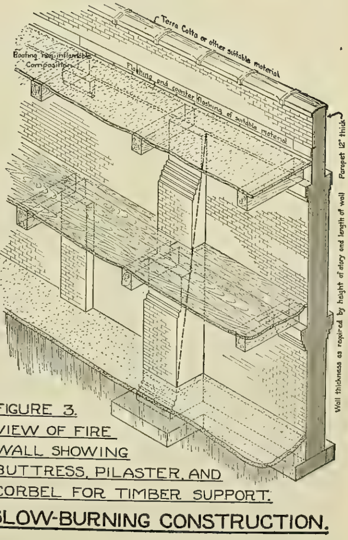

Terra Cotta or other suitable material
Roofing non-inflammable Composition
Flashing and counter flashing of suitable material
Parapet 12" thick
Wall thickness as required by height of story and length of wall

FIGURE 3.
VIEW OF FIRE WALL SHOWING BUTTRESS, PILASTER, AND CORBEL FOR TIMBER SUPPORT.

DETAILS OF FIRE BREAKS FOR SLOW-BURNING CONSTRUCTION.

Disconnected platforms affording no serious fire hazard to the warehouse are discussed under the head of "Independent platforms and sheds."

The surface of a concrete platform, for any use where subjected to constant trucking, should be of such hardness as not to wear rapidly. This is secured primarily by a top-dressing, or surfacing, of concrete mixed with a liberal quantity of cement; or by the use of sand which is not excessively coarse. Sand having grains of graduated size is preferable. Such a mortar is dense and presents a surface that wears down slowly and evenly. Further hardness may be secured by the use of special preparations which are on the market. Some of these are mixed with the mortar and others are penetrating liquids for application to the surface after the cement has set. The comparative merits of these preparations should be determined before they are purchased.

FLOOR OPENINGS.

Floor openings never should be permitted to form a direct communication between two inclosed floors or compartments. Elevators and hoist should be located on the platforms and isolated from all openings into the compartments. Where bale chutes and stairs are required, they should be placed in a similar manner.

SLOW-BURNING CONSTRUCTION.

ADVANTAGES AND DISTINCT FEATURES.

Slow-burning construction is well suited to the requirements of the cotton warehouse, although this construction does not afford such a high degree of protection as fire-resistive construction. The storage house for cotton, however, presents a combination of values of distinct contrast to many buildings in that the value of the cotton stored so very far exceeds the value of the building which protects it. Although the building of reinforced concrete will remain practically undamaged after its contents have been entirely consumed, the building of good slow-burning design will retard materially the action of fire and provide very favorable conditions for extinguishment. With acceptable designs for warehouse compartments of this construction, fire frequently can be confined to the section in which it originated. Hence the compartment is still the unit of the warehouse, as it is in case of the fire-resistive construction. The same general influences control its preferred size and proportions except that its limitations must be fixed entirely by walls, the floors not serving to separate compartment units, in case of multiple story construction.

Slow-burning construction—sometimes called "mill construction"—consists of substantial masonry walls and heavy timber framing with thick and closely laid floors and roof, all arranged so that no concealed spaces, or pockets, are formed. Although this may be considered a brief definition, there are a number of essential details which should be adhered to if the building is to be worthy of its name. For example, timbers which are carried at the end by walls should be supported there in such manner that failure and falling of the timber would not damage the wall. The value of proper construction, in this particular, is shown by the photograph in Plate XXII, figure 1, in which case heavy timbers resting on corbels have fallen without damage to the wall though an entire compartment was consumed. It is true that the first requisite is control of the fire, but a close second consideration is that damage be restricted and repair made easy.

Some general features of slow-burning construction as embodied in a well-designed warehouse are shown in Plate XXII, figure 2. The cast-iron post cap gives a good connection between the post and timbers.

DIVISION FIRE WALLS.

Division fire walls should be of the same material as that specified for such walls of the fire-resistive construction and the general requirements are the same. There is, however, one factor to be considered here that is of greater importance than it is in the case of fire-resistive construction—that is, stability against overturning or buckling from heat. In the construction having reinforced concrete floors and roof, these supply a rigid tie to the wall; but in slow-burning construction, the wall must stand upon its own merits and must sustain the shock of falling timbers and goods. Sufficient stability usually is supplied by the thickness and other proportions specified previously for brick walls of the bearing type.

An excellent fire wall is shown in Plate XXIII. The compartment was full of cotton, which was entirely consumed. Note that the heavy tapering buttresses held this unusually long wall against the buckling and overturning which a severe fire frequently causes.[1]

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[1] The resistance to buckling of the long wall under the test of heat may be supplied by cross walls or buttresses instead of the additional thickness previously described. Buttresses should be placed at intervals not exceeding 100 feet and preferably of 50 feet. This type of buttress (shown on Pl. XXVI, fig. 3) should be built with and into the wall and not merely against it. The combination of vertical surfaces and off-sets should be such as to be equivalent to a tapering buttress (indicated by the heavy dotted line) having a projection at the first floor of one-tenth the height of the wall; the face (or thickness measured parallel to the wall) should be 24 inches. If concrete is

In order to form a complete fire break the division wall in slow-burning construction must extend well through and above the roof, this projection usually being 3 feet. If the roof has a monitor or combustible skylight within 50 feet of the wall, the parapet should extend to the level of the top of such structure. Moreover, the ends of this wall must project through the eaves or cornice of the roof in the event that such combustible material overhangs the exterior wall. This is shown by the drawing in figure 17. The portion of the wall projecting above the roof, or that extending above the bottom of the roof timbers, is known as a "parapet" or "parapet wall," whereas the extension of the ends through the cornice may be termed a "corbeled extension," or "wing wall." Openings in the division wall are quite as undesirable in this design as in fire-resistive construction and when openings are necessary they should be protected in an equally effective manner.

All parapet walls should be finished on top with a suitable material to preserve the mortar joints there. This protection is usually supplied by a coping of terra cotta or concrete. Such copings are shown by Plate XXVI; figure 2 shows a concrete coping and figure 3 a terra cotta coping.

THE EXTERIOR WALL.

The exterior wall should be of the same material and design as described for similar walls of the bearing and curtain types for fire-resistive construction. The proportions stated there are sufficient to resist the pressure of ordinary windstorms provided the wall is not excessively long and tall.

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used, a tapering buttress as indicated by the dotted lines will be cheaper, while the design shown is suitable for brickwork.

The pilaster, such as is shown by Plate XXVI, figure 3, is of value in supporting loads carried by the wall and gives some added stability to the wall, particularly if it is tall, but the pilaster is not a satisfactory substitute for the buttress in resisting buckling from expansion.

Walls longer than 200 feet should contain expansion joints at intervals not exceeding 200 feet, and should have these free ends buttressed.

The parapet height is not figured into the height of the wall for purposes of determining thickness.

In the rare instances when a panel wall is used, the same principles should be applied to it except that the total thickness and breadth of each pilaster (or, more properly, column) should be, at the bottom, equivalent to one-eighth of this height. At least one beam should be used near the top of the wall, the beam having a depth of 12 inches or more and a breadth equal to the greatest thickness of the column but not exceeding 24 inches. This broad beam should supply the necessary resistance to buckling from expansion. The thickness of the panel would be subject to the same limitations stated for similar use in the fire-resistive construction.

Fire walls for one story buildings with a low story height of only 9 feet may be of 12 inch brickwork.

Walls longer than 100 feet and not tied by cross walls should be braced at intervals of 100 feet by buttresses similar to those in Plate XXIII, figure 2. The top of the wall should extend above the roof to form a parapet 3 feet high if there is an exposure; this arrangement is shown in the photograph just referred to. If there is no serious exposure, the wall may terminate as a parapet only 18 inches above the roof, or the wall may be finished with a corbel supporting a metal gutter as shown in Plate XXIII, figure 2. In the latter case it is important that the division fire wall provide the corbeled wing projection shown. It is preferable that there be no overhanging cornice as this is a source of fire hazard.

Walls not terminating with a parapet should have suitable wrought iron timber anchors built in and secured to the framing, in order to resist the lifting action of wind. The size and design of the anchor depends on the arrangement of framing.

Openings in the wall should conform to the same size and arrangement as stated for fire-resistive construction. Doors may be of thick and substantial wooden construction if there is no serious exposure. Windows should be metal glazed with wire-glass.[1]

FRAMING.

The usual arrangement of roof and floor timbers is such that the end of the timber is supported by the division wall. The end of any timber supported by a wall should rest freely upon a ledge, such as an offset or corbel, and not be built solidly into the wall. The free support permits the timber to fall without damage to the wall as previously illustrated. This is one of the most important details of slow-burning construction, and failure to observe this requirement leads to serious damage to the building and also rapid spread of fire. The drawing, Plate XXVI, shows such construction in figure 3 where the floor timbers are supported by corbels and offsets or by pilasters and the roof timbers are supported by corbels. These timber-ends often may rest directly upon the brickwork provided sufficient bearing area is supplied for the comparatively light load generally sustained. Timbers parallel to and supported continuously by the wall, such as frequently occur in the exterior wall, which support the ends of floor or roof plank, should be lightly anchored to the wall by bolts for the purpose, although the bearing should be directly on a ledge formed by an offset or corbel.

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[1] A condition which requires that doors be constructed as a fire door is occasioned by the use of wood platforms. This protection should also be used in the case of doors in one story placed under those above and not separated by a reinforced concrete platform. Wooden doors are used only where no severe exterior exposure is anticipated. A wooden door is satisfactory if all of the provisions here stated are fulfilled, but the fire-resistive door is much better. In any event, doors should fit close to the wall and threshold. If the exterior exposure is very severe, the wall and all openings should be constructed as in a fire wall.

Timber ends supported by posts should have a direct bearing over the post and have a supplementary connection from an iron cap or wood bolster such as is shown by figures 4 and 5 of Plate XXVI. Where a floor is supported, the post above this floor should be tapered and carried between the ends of the timbers of the floor below to a firm bearing on the column bolster or cap; the ends of the abutting timbers should be beveled so as to secure a direct bearing. Such construction is shown by Plate XXVI, figure 5. The timbers are secured by lag screws connecting them to the bolster which is in turn spiked to the post. This bolster is of further value in stiffening the timbers against deflection under load. The iron cap of suitable design may be used in place of the bolster. Use of the iron cap is to be preferred for one-story buildings where the use of power trucks is contemplated. In such cases the post should be securely framed to reduce the likelihood of its being knocked out by the truck. Posts supporting the roof should be secured to it in such manner that slight lifting of the roof by wind would not allow the post to fall. The post which is supported at the first floor should always rest on a cast-iron plate in order that there may be no penetration of moisture from the pier into the wood to cause decay, and to equalize and distribute the load over sufficient area of the pier. (The pier should, of course, be of substantial masonry such as was described for use under ground). The lower end of this post should contain a hole about 1½ inches in diameter and of equivalent depth which should fit over a lug, or knob, formed on the bearing plate. This gives stability against displacement by blows from trucking. The framing described is simple, economical, and is most satisfactory in behavior when subjected to fire. Timbers should be dressed on all exposed sides and have corners chamfered, or beveled, and splinters removed.

For preservative and fire retardant treatment of wood, see the concluding paragraphs under "Semi-slow-burning construction."

FLOORS.

Planking for floors above the ground and for the roof should be thick. All exposed sides should be dressed and edges should be well matched by being tongued and grooved or splined, preferably the latter. (In splined construction the edges of the plank provide a deep, wide groove into which a wooden strip is fitted tightly.) This construction insures a close joint, which prevents the ready passage of flame and retards the leakage of water used in extinguishing fire.

It also tends to prevent the warping which is particularly damaging to roofing. The planking should be securely nailed to timbers and all the joints should be close. Over this should be laid one layer of waterproof paper covered with a durable wearing floor about seven-eighths of an inch thick. There should be provided, however, an open joint of about one-half inch at the junction of the plank edge and wall to permit the plank to swell in damp weather; disregard of this precaution results in buckling on the floor and, occasionally, in displacement of the wall. For floors, this space should be closed by a light strip of hardwood loosely nailed at the top of the floor and carefully fitted to the wall, as this serves in case of fire to retard the passage of flame from one story to that above. Instead of this strip, or in addition to it, the masonry wall should provide a ledge, 2 inches or more wide, just under and close to the floor plank. This prevents the quick spread of fire from one floor to another.

The first floor should rest directly on the earth and should be constructed as described for fire-resistive construction. Where this entails prohibitive cost, as may be the case on a rolling site, the first floor may be constructed as described for other floors. In such case it is desirable that the timbers supporting this floor rest directly on masonry piers. These floor timbers should not be nearer than 18 inches to the ground and the space under the floor should be ventilated (through the exterior wall) if rapid decay is to be avoided.[1]

Openings seldom should be permitted in floors and when unusual conditions make such openings necessary the opening should be inclosed by fire walls with all wall openings fully protected by roomy vestibules and double fire doors automatic in operation. Such openings should be avoided by placing stairs, elevators, hoists, and bale chute well removed from all wall openings and so as to connect platforms.

ROOFING.

Roofing should conform to the same requisites set forth for material used in fire-resistive construction, although there is slightly more latitude here inasmuch as the material should be applied with nails.

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[1] Distinction between slow-burning and the usual light joisted construction has been drawn by fixing certain minimum requirements for sectional area and dimension of planking and timbers. It is generally conceded that roof planking should not be less than 2½ inches and floor planking should not be less than 3 inches thick, with a permissible reduction in thickness of three-eighths of an inch taken off in dressing. Timbers should have a minimum sectional area of 64 square inches (equivalent to 8 inches square for columns) and should not be less than 6 inches in any dimension. (This does not refer to light wall timbers continuously supported by a ledge, these timbers usually being 4 inches by 8 inches.) In any event, the size of the timber should be such that charring to a depth of one-half inch on all exposed sides would not reduce the strength of the timber more than 20 per cent and in no case to the point of failure. All timber and planking should be dressed on all exposed surfaces. It is desirable

The variety of material and construction is usually limited to those adapted to roofs of very slight pitch since this slight incline is preeminent for warehouse designs. That the roofing material should be non-inflammable is of even greater importance for this construction than for the fire-resistive. In the case of a concrete slab the danger would be limited to access of sparks through ventilators and skylights and all fire damage would be confined to the possible loss of the roofing material. On the contrary, for slow-burning construction, the roofing material itself must serve as a protection to the roof planking against exterior fire. Furthermore, the roofing is called upon to resist the lifting, or "sucking," action of wind and, therefore, must have either considerable strength or weight or both.

There are certain elements peculiar to a fire in a cotton warehouse which render unsuitable for roofing some materials, such as tin and sheet iron, which are well suited to other purposes. It is true that these materials are proof against spark hazard from external sources, but they present a serious handicap to the extinguishment of fire which has originated in or gained access to an individual compartment. Some critics hold that the chief objection to tin or sheet iron is that when the supporting framing is burned away the metal falls upon the cotton and prevents effective application of water with a consequent heavy loss of the cotton. Others hold that it is better in case of fire that a hole be burned through the roof so as to permit the direct escape of heat and smoke in order that all openings may be used more readily for application of water. Such action is retarded when the burning framing with metal clinging to it falls bodily on the cotton. The composition roofings, on the other hand, break up under such conditions and do not present any material hazard. Certainly the feature of salvage from a cotton fire is sufficient to make the use of metal roofings inadvisable unless applied over 2-inch planking,

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that the corners of timbers be beveled or chamfered, but in any event splinters on corners should be removed as these afford ready facility to ignition.

The wearing or surface floor should be laid diagonally or at right angles to the heavy floor plank. The surface floor may be pine, though a hardwood such as maple should be used where much trucking is contemplated.

The waterproof paper should be turned up at wall and columns 6 inches. This construction is very desirable for warehouses used by cotton mills where fire or water damage may result in a loss greater than the commercial value of the cotton because of expense and delay in making replacement with cotton of like character.

The "Regulations of the National Board of Fire Underwriters Governing Standard Mill or Slow-Burning Construction" is a concise specification of the very best practice. Every engineer and builder should endeavor to follow these recommendation which were prepared by the foremost engineers engaged in commercial, scientific, and fire-prevention work.

which would not collapse quickly. Even then, it should be adopted only with great reluctance. The roofing most fully suited to the requirements of the nearly flat roof of the cotton warehouse is tar and gravel of good material carefully applied. Its cost of upkeep is very low, while with a tin roof the cost of painting required is considerable.

The junction of roofing with parapet walls should be made watertight by extending the flashing an ample distance up the side of the wall and counter-flashing with suitable material built into the brick joint or suitable recess.[1]

ROOF OPENINGS.

Roof opening for the storage or compress compartment of slow-burning construction should conform in all particulars to the requi-

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[1] There is now on the market a type of tile, or wall block, which provides a "raggle joint" for holding counterflashing. The eaves of the roof may extend even with the outside of the exterior wall and be finished with a hanging gutter fitted close to the top of the wall, or the exterior wall may continue above the roof to form a parapet. When this latter and better method is adopted, care should be exercised to provide ample capacity for the outlet conductors in order that excessive water may not accumulate on the roof and encroach above the flashing. As a further safeguard against such an occurrence if conductor pipes should become clogged, scuppers or openings should be provided through the parapet, the inner end of the scupper lining being soldered to the flashing and the outer end arranged to discharge water freely.

The scupper preferably should be about 5 inches high and 12 inches wide and should be so set that the top of the opening would not be above the top of roof flashing and the bottom would not be so low as to permit discharge from the scupper except in the event of stoppage of conductors.

Flashing and counter-flashing should be of durable material and usually should be metal. Copper is the best material for this purpose, but its cost at this writing makes its use prohibitive. When used it should be of the thickness known as 16-ounce, the "hot rolled" metal being suitable. Galvanized iron makes an excellent and economical flashing. Its thickness should be from 24 to 27 United States standard gauge. Care should be exercised to see that the material used does not show cracking or flaking off of the zinc coating when the metal is bent in the necessary manner. Roofing tin may be used, but is less desirable than the other materials mentioned. Such tin plates should be of the quality known as "40-pound" tin coating, and this coating may be on the lighter weights of sheet iron. Tin flashing always should be well painted on both sides. Joints in any flashing should be soldered and allowance made for expansion. The counter-flashing (which is built into the wall and turned down over the flashing) should be in long but independent sections, well lapped at joints. Guttering should be of galvanized iron, usually of No. 24 United States Standard gauge.

It is of great importance that there be no penetration of water at the junction of roof and parapet. Although the resulting damage to the cotton may be negligible, such moisture causes rapid decay of the ends of timbers, with a frequent result that such timbers which are otherwise sound must be replaced.

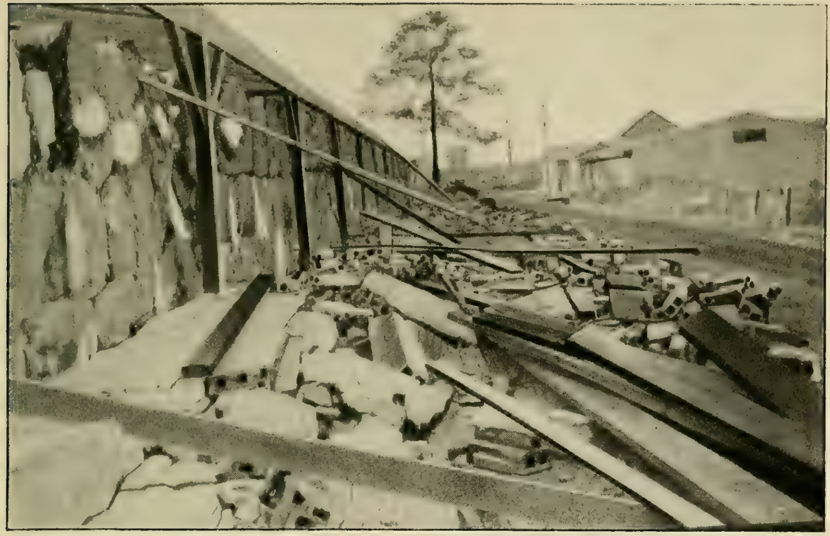

FIG. 1.—LIGHT TILE WALL DEMOLISHED BY WINDSTORM.

Note that the wall fell outward; this shows why pilasters should be placed on the outside of a wall of light material.

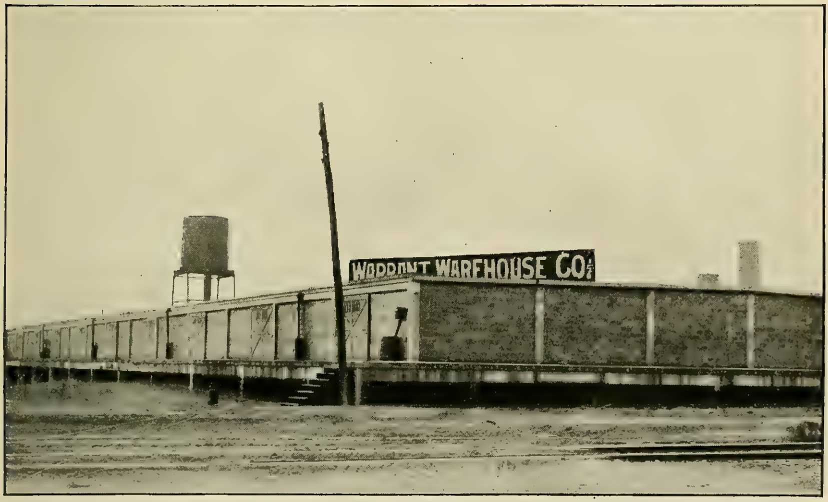

FIG. 2.—A WAREHOUSE IN WHICH HOLLOW TILE IS USED TO THE BEST ADVANTAGE.

Note that the frame, roof, and platforms of the building are of reinforced concrete.

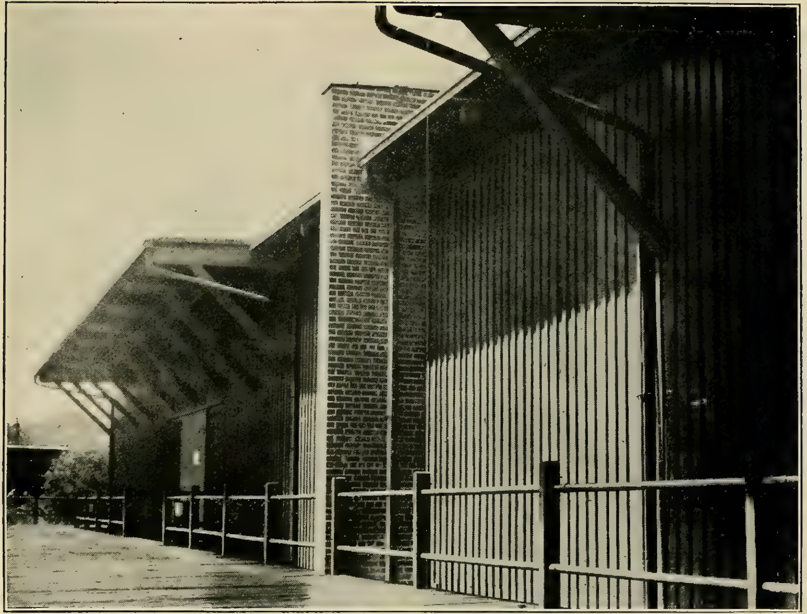

FIG. 1.—THE PLATFORMS SET OFF FROM THE BUILDING IN ORDER TO MAKE MORE EFFECTIVE THE FIRE BREAK FORMED BY THE WALL EXTENSION.

Note that the roof overhanging is drawn in on each side of the fire wall.

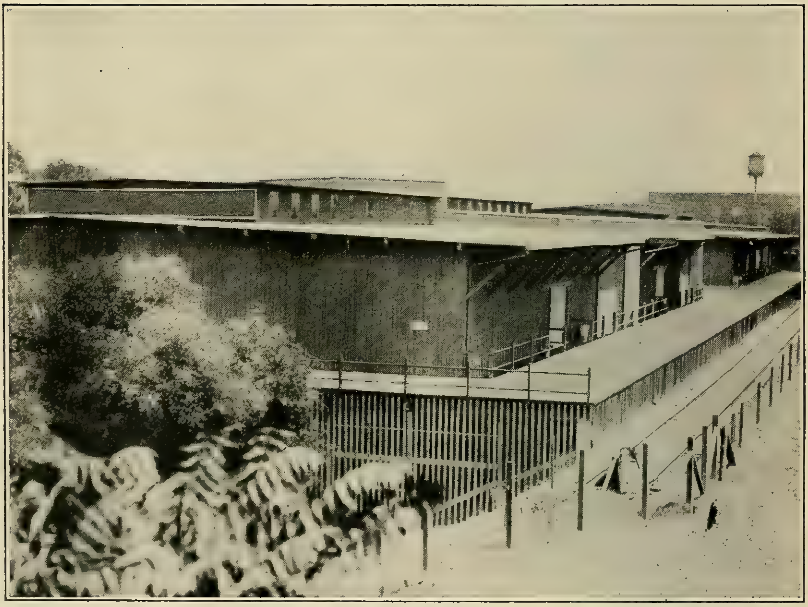

FIG. 2.—A SEMI-SLOW-BURNING WAREHOUSE BUILT AGAINST A RAILWAY FILL.

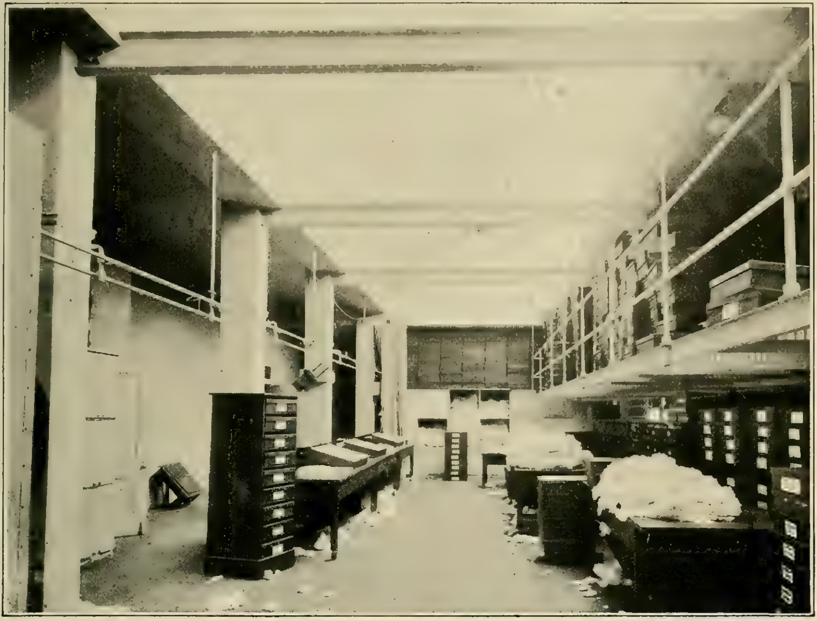

FIG. 1.—INTERIOR OF A CLASSING ROOM SHOWING EXCELLENT DISTRIBUTION OF LIGHT EFFECTED BY THE SAW-TOOTH SKYLIGHT FACING THE NORTH.

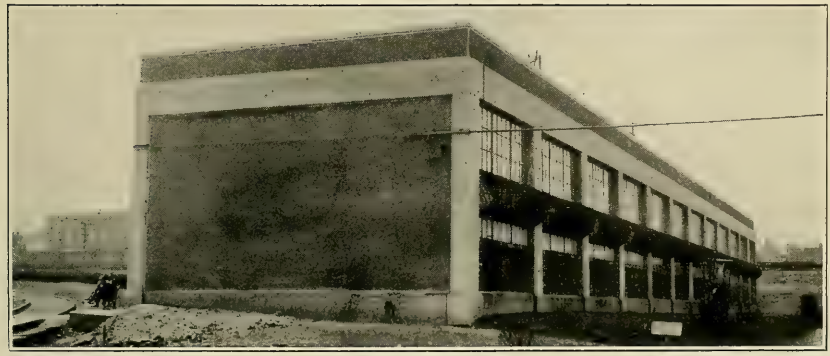

FIG. 2.—A VIEW OF AN EXCELENT CLASSING ROOM AND OFFICE.

sites set forth for such openings in the fire-resistive roof. Special care should be exercised to see that a tight joint is made at the ventilators and skylights.

PLATFORMS.

Platforms should be paved or, if elevated, built of reinforced concrete. Wooden platforms are a source of great expense for upkeep and present a good opportunity for the origination of fire. All things considered, the paved or reinforced concrete platforms are more serviceable, and, eventually, are more economical. If wooden platforms are used they should be of heavy timber, and the warehouse doors should be protected as previously described.

In view of the frequent reference to requirements of the construction for warehouses several stories in height, it is scarcely wise to conclude this portion of the discussion without pointing out the hazard such additional stories entail. The single-story warehouse of any construction affords decided advantage in dealing with a fire and is especially advantageous in the case of slow-burning construction. However, if conditions demand the storage of cotton without tiering, this single story entails a prohibitive cost of the plant per bale capacity, particularly if adaquate yard hydrant piping or sprinkler equipment is provided. In such cases there is no serious objection to providing three low stories if all stories of the compartment formed by the division fire walls contain a total of not more than 144,000 cubic feet. The resulting area (stories being of equal height) is suitable for convenient storage of 1,000 bales of uncompressed cotton or 1,500 compressed bales. Additional stories not only involve subjection of an excessive value of cotton to a single possible fire, but render the use of hose streams less effective. For slow-burning construction, not more than four stories should be countenanced under usual conditions, and these stories should be low, permitting the storage of only one tier of bales on end.[1]

Extreme caution should be exercised in the use of unprotected steel in combination with any timber construction. The weakness of steel for such use is shown in Plate XXV. In this building both steel beams and timbers were used owing to a shortage in available steel beams. A fire which damaged the timbers but slightly caused the steel beams to twist and sag as shown by the photograph. The most dangerous use of steel from a fire hazard standpoint is the use of steel rods in truss beams. There is a temptation to use this construction for increasing the span of beams and so reducing the number of columns, particularly in the compress compartment.[1]

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[1] Additional stories may be provided by making alternate floors of fire-resistive construction, such as reinforced concrete. Even in such event, a limit of four stories is preferred and six stories should be the final limit, the third and fifth floors of reinforced concrete and all floors provided with platforms of reinforced concrete.

SEMI-SLOW-BURNING CONSTRUCTION.

A modified type of slow-burning construction for cotton warehouses is in very general and satisfactory use. This type of building is exactly like the slow-burning construction already described except that the exterior walls are of light frame and the division fire walls are modified in such manner as to form an effective fire break in these inflammable exterior walls. Also the omission of the durable top floor and waterproof paper over the heavy planking is permissible and in keeping with the cheapness of this construction. This combination may be called semislow-burning construction. It is frequently spoken of as "wood-end" construction, though this is a rather indefinite term. A general view of such a building is shown in Plate III, figure 1, and is referred to in the beginning of this discussion. The value of the semi-slow-burning construction lies in the economical restriction of cotton subject to a single fire. Provided the design of the division fire wall and the wood end is correct, this construction is very satisfactory for buildings properly separated and not seriously exposed to other fire hazard. This design is especially economical of construction in communities where lumber is readily available and masonry materials are scarce.

EXTERIOR WALLS.

The exterior walls constructed of light frame afford advantages in some cases to firemen, since the boards can be pulled off readily, thus providing openings through which hose streams may be played effectively upon the fire. The disadvantage of the wood-end wall is that it does not afford adequate protection from fires of exterior origin. Therefore these two considerations are favorable to the use of very light framing, such as 2 by 4 inch studding, carrying lapped siding, or weatherboarding, combined with heavy posts that support the timbers carrying the floor or roof plank. Thus if the fire gains sufficient headway to make destruction of the light inclosure necessary it may be accomplished easily; or, in the event of the fire having made dangerous progress, the light inclosure may be burned away and still leave the roof or floor adequately supported for a time. The siding should be applied horizontally and with edges of boards well lapped so as not to permit the entrance of sparks. Vertical boarding is less desirable unless the joints between planks are well stripped. Siding may be the ordinary resawed beveled weatherboarding, either sized or dressed. The dressed material is to be preferred unless the wall is to be whitewashed, in which event the rough material affords a better surface for the whitewash. This frame wall may be left unfinished or it may be whitewashed, stained, or painted. Whitewash affords good protection against attack of flame, but the result is unsightly unless the mixture is colored and frequent applications are made. Stains made with creosote may be used, or the wall may be painted with such paints as do not burn readily.[1]

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[1] Usually the steel rod equivalent to 1 inch square is subject to a stress of 16,000 pounds which it readily withstands at a normal temperature, but with ordinary temperatures reached in a fire this strength is reduced quickly to so low a value as to make failure certain and prompt.

Steel or wrought-iron timber hangers or post caps are less objectionable than steel truss rods, as a partial yielding of the timber hanger does not alter as seriously the mechanical stress which remains equal to the sheer load of the beam.

If it is necessary to secure spans longer than is economical with timbers, trusses may be used provided all members (both tension and compresion) are of wood having the dimensions of no side less than 6 inches and are such that charring of all sides to a depth of one-half inch will not reduce the strength of the member more than 20 per cent. Steel or iron should be used only for bolts enclosed or insulated by the wooden members.

Clay wall tile may be used as a substitute for the frame wall of single-story buildings. The thickness of tile need be only 6 or 8 inches, provided it is suitably tied or braced against wind and guarded from the piling of cotton bales against it. These precautions are absolutely essential. Disregard of them with consequent failure from wind is shown in Plate XXVII. Here the light thin tile wall was completely demolished by wind. It should be noted that the wall fell outward—a very common result of the "sucking" action of wind on the unexposed side of a building. It is stated on good authority that the storm which destroyed this wall was not extraordinarily severe. Clay tile may be used satisfactorily, however, for thin walls, provided the wall is sufficiently braced by pilasters or other device. The wall should be built independently and outside of framing supporting the roof. This reduces the extent of possible wind damage, permits ready breaking through in case of fire and lends itself to economy and efficiency in original construction. Such a wall is economical in upkeep and affords far less spark and exterior fire hazard than the wood end. This type of wall may be termed a paneled tile curtain wall.[1]

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[1] Framing of the exterior wall should be constructed so that sills will be raised above the ground and protected from moisture. It is desirable that the light sill, or "shoe," be raised about an inch above the platform and with the boarding overlapping, as a protection from the weather. This suggests an advantage of horizontal siding over vertical boarding, as in the first instance only one or two boards would be subject to rapid decay, whereas the ends of all vertical boards would be subject to decay from moisture. A very economical manner of framing is that used in the large export plant illustrated in Plate II. In this instance the paving that forms the floor and platforms is laid continuously and supports the light weight of the wood-end wall. The sill is 4 by 4 inch pine cut in between the main roof supports. The ends of this sill rest on the cast-iron plate carrying these roof posts, and the sill is supported at intermediate points by small cast-iron plates having a lug, or knob, projecting into an auger hole bored in the sill to prevent displacement of the support. The main roof-supporting posts, for both the wall and interior locations, rest on plates supported by small concrete or brick piers. Where such construction is used, it is important that the floor be raised about one and a half inches above the platform, the change of level being made at doorways by a slope inside the compartment and elsewhere by an abrupt drop or a slope back of the siding. Otherwise blowing rain will result in water damage to cotton near the walls. Studding for weatherboarding should be set about 24 inches apart. Where there is more than one story the wall for each story should be of separate lengths of studding. The upper wall framing should be carried by the respective floors.

Doors and windows for either the wood or tile wall should be provided in the manner described for masonry walls for slow-burning construction, except that there is never any occasion for doors to be tin covered. It is best that windows be glazed with wire glass in order to reduce breakage. There is no objection to omitting windows entirely so far as dealing with fire is concerned, as either type of wall can be broken through readily. Steel sash are economical when upkeep is considered, even when used in a frame wall, but wood sash may be used if desired.

DIVISION FIRE WALLS.

Division fire walls in their relation to the frame exterior wall are shown by Plate XXVI. The T wall construction is shown by figure 2 of this drawing. The width of the part of the T that forms a section of the exterior wall should be 6 feet. Only very exceptional conditions demand the increase of this length. If a wooden platform is used the portion of the platform adjacent to the T of the division wall should be of concrete. This may be a paved section supported by low wall and earth fill or it may be of reinforced concrete. The exterior wall shown by figure 1 forms fully as good a fire break as the T wall and is much cheaper in construction. If the platform is of wood it should be broken at the division fire wall by a paved section 6 feet or more in length as shown by the drawing. The extension wall itself should project 3 feet beyond the frame or tile exterior wall. Such extensions should not be counted in the length of the wall for determination of excessive length as effecting thickness. Neither is it necessary that the required wall thickness be used for this portion of the wall, as 12 inches is satisfactory. For either design the top of the division wall, including the extension or T section, should extend 3 feet above the roof and should be finished with a coping as described under "Slow-burning construction." As in that instance, the parapet should be 12 inches thick, this same thickness being used for the T wall or the extension for any reasonable height of wall.

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[1] Paneled tile curtain walls should not exceed 15 feet in height. For heights less than 10 feet, 6-inch tile is suitable, while for heights of 10 feet or more 8-inch tile should be used. Pilasters should be constructed at intervals of 10 feet or less on centers and should be at least 1 foot wide. The pilasters should be coincident on each side of the wall and should have a total thickness of at least one-eighth the height of the wall. Tile blocks should be laid with joints well broken and tiles forming the pilaster should be bonded with those forming panels. The pilaster construction requires that these blocks be laid on end. Good bonding is secured by laying metal wall ties, metal lath, or even strips on 1-inch mesh poultry wire in the horizontal joints. This last method is fairly satisfactory and involves extremely little cost. Door openings should be laid up with brick reveals forming pilasters of the usual dimensions. The lintel may be constructed very economically by inserting a steel rod in a row of blocks filled with concrete. The blocks are stood on end in the number required for the lintel, the steel and concrete is inserted, and the lintel is left in this position until the concrete has set sufficiently for use.

The same factors governing preferred designs are to be found here that were pointed out in the discussion of slow-burning construction. The features of compartment size and number of stories are the same. The use of concrete platforms is even more important than in the former case. The exterior wall should be of light framing weatherboarded and should provide sliding wooden doors. Thin tile curtain walls may be used to good advantage, but do not justify a very great increase in cost over the frame. Division fire walls may terminate in either manner described. The T wall costs more but is an advantage if platforms are narrow. The projected extension wall affords fully as satisfactory protection.

The roof of the eaves should extend over the wall about 12 inches. A hanging gutter is a very desirable finish. Wind anchors for roof timbers at exterior walls of frame are of little value, but if the exterior wall is of tile, suitable anchors of wrought iron should be provided at pilasters. Posts should be secured to roof framing.

A good example of this semislow-burning construction adapted to trying conditions of the site is shown in Plate XXVIII, figure 1. Here the basement is well drained and the floor waterproofed. The fire hazard incident to the wooden platforms is minimized by the fact that the platform is really detached from the building as shown in the detailed photograph (Pl. XXVIII, fig. 2). This view also shows the fire break formed by the division fire wall.

USE AND PRESERVATION OF WOOD.

The selection of wood for the cotton warehouse is generally restricted to Southern pine, as the majority of cotton warehouses are located in the southern part of the country where that wood predominates. This natural limitation is not a disadvantage as the several species of pine meet almost every need for timber construction of the warehouse. Southern pine is among the most suitable timber also for warehouses in the Northeast and other sections of the country, but in these locations the relative economy of fire-resistive construction should insure its adoption.

Among the varieties of pine available and suitable for warehouse purposes are those commonly known as longleaf and shortleaf, there being several varieties with more or less distinct characteristics which are very roughly but commonly spoken of under these terms. The longleaf pine is superior for most structural purposes to the other varieties. Some of the chief advantageous qualities that have been accredited to longleaf pine are due to the characteristic long timbers comparatively free from defects. However, it is so nearly impossible (and certainly impracticable) to identify the different varieties of pine after they are sawed into timbers that great dissatisfaction has arisen over the specification of "longleaf pine" and this method is giving place to the "density method" of grading Southern yellow pine.[1]

Economy in the quality of timber used for the cotton warehouse generally should be affected by the use of "dense" timbers for beams and "sound" timbers for posts, all free from serious defects, and acceptance of lumber of a somewhat lower quality for the heavy floor and roof planking. The usual load is so light that the thickness required to affect slow-burning makes defects such as sound knots and cross grain less objectionable than for most purposes. Square edge plank free from wanes (bark or splintered corners) should be insisted upon.

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[1] The basic principle of this method is that pine timbers having a large percentage of summer wood in proportion to spring wood—as shown on the end section by the dark-colored rings being close together or relatively wide or both—is much stronger than timbers of rapid growth as indicated by a small ratio for the area of dark rings. Even that variety of pine generally known as "loblolly" shows a fair degree of strength when dense timbers are selected. The U. S. Forest Service has conducted very complete tests for determining a fair method of arriving at the relative structural merits of Southern yellow pine. The report of the Forest Service was adopted by the Southern Pine Association in January, 1915, and by the American Society for Testing Materials in August, 1915. Now specifications may be based upon the density, which is indicative of the unit strength for perfect timbers, and upon the location as well as the kind and size of defects. The recommendations of the Forest Service as to density and defects and a discussion of the subject is contained in convenient form in an illustrated pamphlet issued by the Southern Pine Association. Very complete data on tests of wood is contained in Bulletin No. 556 of U. S. Department of Agriculture: Mechanical Properties of Woods Grown in the United States, 1917.

Wall siding and other planking which will be exposed to the weather or will be in contact with the earth preferably should be heart material, but, if it is to be kept well painted or is to be treated thoroughly with a preservative preparation, sap lumber may be used.

Wood for fire-door cores—the door designed to be covered with tin—should be nonresinous or nearly so; white pine or cypress is the best material.

Paving blocks of wood are excellent for the compress compartment floor. It is desirable that these blocks be set with a pitch cement and be laid over a 3-inch rough slab of concrete.

The tendency of wood to decay should be checked by either preventive methods or preservative treatment or both. Decay of wood is caused by a fungus which, under moist conditions or through lack of ventilation or infection, affects the wood with alarming rapidity. This growth not only causes rapid deterioration in timbers infected, but spreads to other timbers in the building or in the lumber yard.

From the present knowledge of the subject it appears that the occasional buyer of lumber may find his best protection in a thorough air drying of lumber as it is received. Timbers showing any indication of white mold, which indicates the presence of the fungi, should be isolated. If the presence of "dry rot" is suspected, as soon as the building is sufficiently complete it should be heated to a temperature of 115° F. and held at this temperature for at least one hour.[1]

The firedoor core, or the wooden door proper which is covered with tin, is subject to dry rot, as the absence of adequate ventilation contributes largely to growth of the fungi. The heat treatment described is essential to the life of wood so to be used. The heating should be done before the tin is applied, or preferably before the lumber is nailed together.

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[1] After heating, the building should be thoroughly ventilated and the process preferably should be repeated for four consecutive days. If sprinkler equipment is provided it should be operative while the heating is in progress, care being exercised not to raise the temperature within 50° of the sprinkler head fusing temperature. In the usual case of warehouses not designed to be heated, the heat may be supplied by small stoves located on the ground floor with flues carried out through ventilator collars or openings. If the building is several stories in height, the plank for the upper floors should be laid loosely with 2-inch strips interposed between them and the supporting floor timbers while the heating is in process. (Of course, this requires the cooperation of the sprinkler contractor.) Thermometers should be distributed properly and carefully read, for under such conditions there will be considerable leakage of air and a wide range of difference in temperature at and far above the first floor. It is apparent that extreme care must be exercised to prevent setting fire to the building. The unfinished building and materials should be insured and a representative of the insurance interest should be present while the heating is in process.

In addition to the preventive methods and care described, preservative treatment should be used when trying conditions of humidity or poor ventilation have to be met. Discussion in some detail of such treatment is contained in various bulletins prepared by the Forest Service.[2]

Checking decay already in progress in a building is done best by removing permanently all timbers affected noticeably and then subjecting the building to the process of heating and ventilating previously described. Constant ventilation of the ends of timbers should be assured.

In addition to the strictly preservative treatment described, the application of oil paint to exposed woodwork is valuable. However, no effort should be made to paint wood already treated with creosote, as paint will not adhere to such surfaces. No paint or other surface applications should be made until lumber is dry and heavy timbers should not be painted for a year after cutting. Paint applied to partially green lumber serves to retain the moisture and is conducive to rapid decay.

Fire-retardant treatment for wood has not been developed on a commercial scale applicable to the warehouse. The only practical methods of increasing the resistance to fire offered by this wood construction is a surface application of whitewash or a water paint of similar character, or a few other paints carrying chemicals of fire-retardant properties. The most effective of these are limited to interior use. No such treatment can be relied upon to retard the spread of a hot fire.[3]

Information on the subject of yard piling and seasoning of lumber is contained in Bulletin No. 552 of the U. S. Department of Agriculture: The Seasoning of Wood, 1917.

A very fine discussion on Dry Rot in Factory Timbers is issued by the Inspection Department, Associated Factory Mutual Fire Insurance Companies, 31 Milk Street, Boston.

[2] See U. S. Department of Agriculture Bulletins No. 101: Relative Resistance of Various Conifers to Injection with Creosote; No. 606: Relative Resistance of Various Hardwoods to Injection with Creosote; No. 145: Tests of Wood Preservatives; No. 286: Strength Tests of Structural Timbers Treated by Commercial Wood-Preserving Processes.

[3] Below is a satisfactory formula for whitewash for interior use. For exterior use the glue and rice should be omitted and it should be remembered that no whitewash is really satisfactory when exposed to weather.

Slake one-half bushel of unslaked lime with boiling water, keeping it covered during the process; strain it and add a peck of salt dissolved in warm water; 3 pounds of ground rice, put in boiling water and boiled to a thin paste; one-half pound powdered Spanish whiting and a pound of clear glue dissolved in hot water; mix these well together and let the mixture stand for several days. Keep the wash thus prepared in a kettle or portable furnace. and when used put it on as hot as possible with painter's or whitewash brushes.

KING PLAN.

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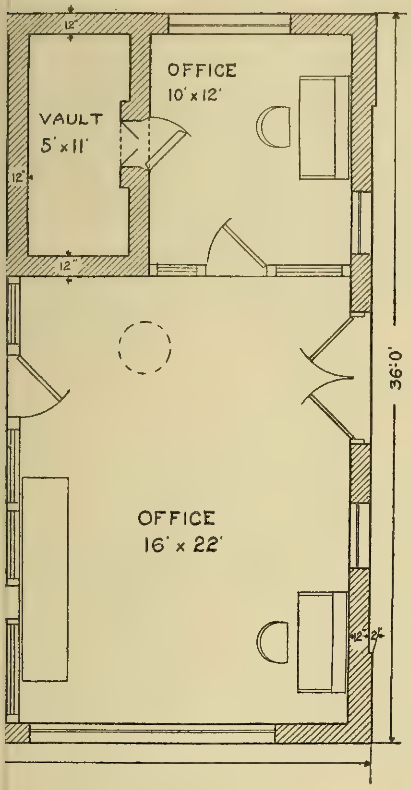

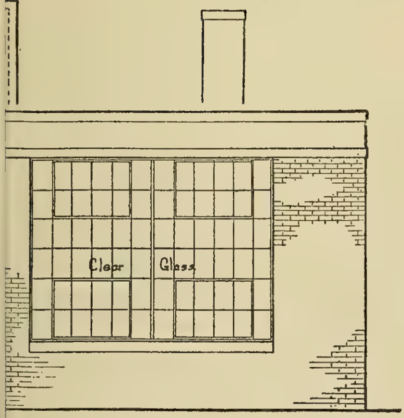

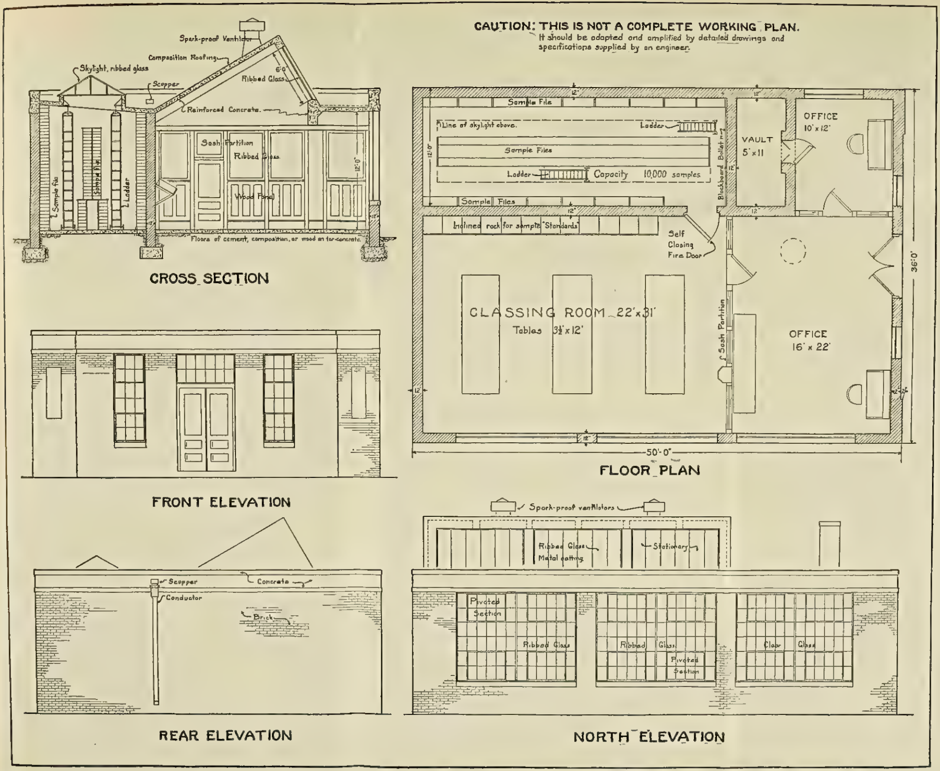

CAUTION: THIS IS NOT A COMPLETE WORKING PLAN.
It should be adopted and amplified by detailed drawings and specifications supplied by an engineer.

Plan of Combined Office, Classing Room, and Sample File Room.

FRAME CONSTRUCTION.

Frame construction for the cotton warehouse may be used in some cases. Such buildings should not be of the ordinary joisted construction, with very light rafters and thin sheeting. The roof should be of the same construction as that described for semi-slow-burning, and the walls should be the same as those used for the " wood end." It is essential that such buildings be well separated, a distance of 100 feet being required between each building and any other building. Such an arrangement generally is not economical except in case of very low value of real estate. The cost of yard hydrant piping is increased very much by this necessary scattering of buildings.

If conditions warrant the frame construction it is well to arrange the buildings in a straight line in order that possible expansion of capacity may be effected by closing in the intervening space, thus forming additional compartments in such manner as to be divided by fire walls suitably placed. Therefore it is well to adjust the area and height of the buildings in such manner as to give for them and the future additions the capacity advised for compartments. Like the semi-slow-burning design, one story is most desirable and two low stories should not be exceeded. Where two stories are used, an inclined runway, or platform, may be provided in order that cotton may be trucked to the higher level.

The construction of the roof—and floor, if there is an intermediate, or second, floor—should be of the heavy slow-burning type as this will greatly facilitate the extinguishment of fire and limit extent of damage. Moreover, such construction is but little more expensive than the light frame construction when the element of labor cost is considered.

"IRON-CLAD" CONSTRUCTION.

The type of construction commonly known as " iron-clad," or the warehouse built of a light wood frame having sides and roof covered with sheet iron, fulfills its greatest usefulness in the case of isolated small warehouses and is used largely on account of the economy with which it can be constructed. This construction is practically proof against exposure to sparks. However, the thin metal affords but little protection against heat to the framing and therefore the spacing of the buildings with reference to each other and surrounding exposures should be the same as is recommended for the frame warehouse.

The chief objection to the iron-clad building is that in case of fire the supporting framing is destroyed very quickly and the hot metal sheets fall upon the cotton and thus prevent the effective application of water. The result is that the amount of salvage from such fires is very small.

For some climates the iron-clad warehouse has a certain disadvantage from the standpoint of cotton storage because of the loss in weight caused by excessive drying-out in the great heat. This, however, is not an inevitable result as it depends upon the condition of the cotton when deposited, the local climatic conditions, and the period of the year during which the warehouse is used for cotton storage. The field for this type of building may be considered as limited to the small country warehouse.

AUXILIARY STRUCTURES.

Most warehouse plants require other structures besides the warehouse buildings. The number and character vary with the size of the plant and the nature of the business. Such structures may include detached platforms and sheds, classing room, sample file room, office, hose (or hydrant) house, pump house, and boiler house. Generally speaking, the type of construction used for these is independent of that used for the warehouse itself.

DETACHED PLATFORMS AND SHEDS.

Detached platforms, either open or covered by sheds, afford great convenience for receiving, weighing, and sampling cotton. The extent and arrangement depends on the arrangement of the plant and whether or not receipts are from wagons or cars. In any event such facilities should be ample from the standpoint of convenience to the management and the public and should allow the adequate protection of cotton from weather and fire. Consideration should be given to the type of scales used for weighing and the methods of handling employed.

Platforms may be constructed of concrete and may be either elevated and of the reinforced concrete design, or may be simply a pavement resting on the ground or on an earth fill surrounded by low retaining walls. The pavement is the less expensive usually. Such platforms afford an excellent surface for trucking, present in themselves no fire hazard, and require practically no expenditures for upkeep. If such construction is not feasible, heavy frame and planking on the order of slow-burning construction may be used. In the latter case it is desirable that supporting piers of masonry extend up to the floor timbers as this eliminates framing and bracing which contributes to accumulation of trash under the platform with the consequent fire hazard and general unsightliness. For this reason, also, the space under the platform should be inclosed by boarding.

Sheds should not be used in courts between buildings unless the warehouse is of slow-burning or fire-resistive construction. Even then the shed should not extend within 25 feet of the warehouse. Shedded courts combined with "wood-end" buildings, while protecting the cotton under the shed, tend to make the whole plant or large sections of it a single fire risk.

Sheds of the open type used over platforms or independent of them may be of fire-resistive, slow-burning, or iron-clad construction. For most situations the use of the shed does not justify the cost of fire-resistive construction. The slow-burning construction is generally most suitable for this use. Sheds covering more than 25,000 square feet should be divided by fire walls so that no area will exceed this amount. Fire doors in such a wall should not be used unless inclosed by a vestibule as described previously. Division fire walls for this use should always terminate with the T end, which should be 20 feet long.

CLASSING ROOM AND OFFICE.

A properly lighted room for grading the cotton samples is very desirable for many plants. Such a room is shown by the photograph in Plate XXIX, figures 1 and 2. The lighting here is excellent for the work as the windows and saw-tooth skylights are turned to the north so as to maintain a uniform intensity and diffusion of light as far as possible. Windows and skylights should be of ribbed glass and walls should be painted a light grey in order to minimize the glare. The tables shown afford ample space for handling of samples. Racks or tables for the boxes containing copies of the Official Cotton Standards of the United States may be placed for convenient reference.[1]

A file room for retention of samples of cotton stored is desirable and frequently is necessary. Some plants used an entire warehouse compartment for samples, but a detached building with the file room adjoining the classing room is preferable. Shelves should be so placed as to insure quick location of any sample.

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[1] See U. S. Department of Agriculture, Bureau of Markets Service and Regulatory Announcements No. 6, 1916, and No. 41, 1919.

Office space is needed in proportion to the size and business of the plant. The office should provide ample vault space for safe-keeping of all records. The character of the vault used should be suited to the possible test it might be subjected to. Usually a vault of 12-inch brick or reinforced concrete walls and roof of reinforced concrete with approved steel doors is satisfactory. It is important that the office be in a separate building from the warehouse, since each constitutes a hazard to the other when combined.

A plan for a combined office, classing room, and sample file room is shown by Plate XXX. This plan should fill the requirements for a plant of 10,000 bales capacity. The drawing indicates reinforced concrete construction with steel sash. Fire-resistive construction is most desirable for such a building, and should always be used for protecting records and samples. Such buildings should be detached and well separated from the warehouse.

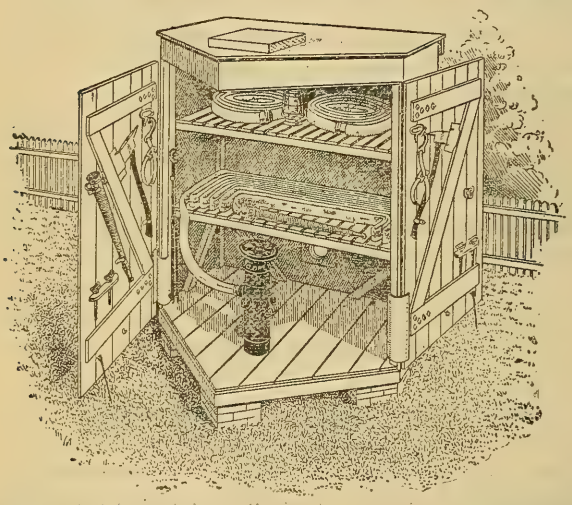

FIG. 7.—Design recommended for all hydrants, and especially for three and four way hydrants, as the attachment of the hose to the side outlets of the hydrant without any sharp bends is rendered possible.

HOSE HOUSES.

Hose, or hydrant, houses should be provided at each hydrant. The requirements for these have been so well worked out and standardized by the insurance boards that it is sufficient to state here that detailed plans and specifications for hose houses may be secured by application to the National Board of Fire Underwriters or the National Fire Protection Association. A view of one type of hose house is shown in figure 7.

PUMP HOUSE.

If the fire-protective requirements call for a pump house, it should be located in a position well removed from all exterior hazards. Even if the pumps are driven by steam from the boiler, the pump room should be either entirely removed or cut off from the boiler room by a fire wall. The construction of the pump house should be either fire-resistive or slow-burning, the former being the more desirable.

BOILER HOUSE.

If a steam boiler is needed for the operation of a press or other purpose the boiler preferably should be in a house or compartment entirely detached from the compress and storage compartment. The building should be of fire-resistive construction. Slow-burning construction for the roof, however, is satisfactory provided all exposures to other buildings are well protected by parapet walls. If a detached boiler house is not feasible, a satisfactory arrangement is to have the boiler room entirely cut off from the other portions of the building by fire walls. The dividing walls should be solid with all openings confined to the exterior wall and roof.

FIRE-PROTECTIVE EQUIPMENT.

Fire-protective equipment—frequently spoken of as " fire protection "—is of such importance for the cotton warehouse that its consideration should be given at least equal weight with the type of construction to be used. The warehouse owner will do well to consider very complete fire protection as essential and to provide the best equipment he possibly can afford. For many conditions, if capital is limited, it is advisable to determine the necessary appropriation for fire protection and then decide on the type of construction which can be undertaken. At the same time it should be borne in mind that this equipment can be added after the warehouse is built, while the building construction can not be changed readily.

The relative cost at which different features of the equipment may be provided depends in a large measure on the location and the size of the plant. Certainly no warehouse is so small or isolated that it can not be furnished with water barrels and pails, though frequently small warehouses can not provide complete fire-protective equipment. The automatic sprinkler system and yard hydrants, both connected with adequate water supplies, should be provided in all cases possible. Any warehouse having a capacity of more than 1,000 bales of cotton should have either hydrant or sprinkler equipment, and at least one of these forms of protection should be considered absolutely essential. The need for complete fire-protective equipment can scarcely be over emphasized where cotton is concerned.

Watchman service should be provided in many cases. The value of this service varies greatly with the size of plant and character of the service, while very small warehouses can not afford the expense.

WATER BARRELS AND PAILS.

Barrels filled with water and suitably placed are of tremendous value in protecting cotton. That barrels filled with water with fire pails at hand are always a familiar sight to the employees is in itself a valuable asset. The simplicity of this equipment is also advantageous, for even the most ignorant laborer can not fail to understand its use, though he might be confused by valves and extinguishers. It would seem that this subject need not be dwelt upon, but there are many warehousemen who overlook this simple supply of water or who give the matter little attention.

Water barrels should have a capacity of 60 gallons. The ordinary commercial oil barrel with one head removed serves this purpose well. The location of the barrels should be such as to insure attention as well as convenience when needed. The space between doors on the outside of the wall is very good. If the areas are large, barrels may be distributed (in pairs) throughout the compartment. This condition usually exists at a compress. Pails should be kept filled and hung over the barrels, ready for instant use. The pails should be of one of the approved fire-pail designs of heavy galvanized iron. Their capacity varies from 10 to 16 quarts, the 12 and 14 quart size being most common. The bottom should be rounded or cone shaped so that the pails will be used only for the intended purpose. They may be painted red and should have the word "Fire" stenciled on the outside.

The number and location of barrels will depend somewhat on the arrangement of the building and other fire equipment provided. For usual conditions one barrel and two pails per 1,000 square feet storage will be ample. The essentials of location are that barrels are convenient both for use and for attention. A good arrangement is shown in Plate XXXI, figures 1 and 2.

In winter the water in the barrels and buckets should be treated with sodium chloride (common salt) or calcium chloride, either of which will prevent freezing. The fouling of the water may be prevented by the addition of slaked lime (calcium hydroxide) or calcium chloride. Charcoal is also beneficial in preventing odors. Unless water is treated in winter to prevent freezing the value of water barrels may be very much reduced.[1]

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[1] Barrels which are to be used for the sodium chloride solution (unless made with wooden hoops) should be reinforced with three-eighths inch round wrought iron hoops kept well painted, as the flat hoops soon rust out. Barrels which are to be filled with calcium chloride should be coated inside with asphaltum paint to prevent leakage.

The following tables give the quantities of calcium chloride and of sodium chloride which may be added to water and the resulting reduced freezing temperature. The specific gravity table is useful in testing at intervals for determination of the condition of the water. When barrels are refilled (as in replenishing losses from evaporation) care should be taken to insure thorough mixing of the added water; otherwise the fresh water will float on top of the

CHEMICAL EXTINGUISHERS.

Chemical extinguishers are of two general types. One contains a reservoir of water with chemicals so arranged that, when the extinguisher is inverted, the chemicals produce a reaction with resulting pressure which is capable of discharging the water with considerable force. The other type of extinguisher generates a gas which clings about the fire and does not support combustion. While both types of extinguishers are of value in some cases, neither of them should be depended upon for the cotton warehouse or compress, as water barrels and pails are more satisfactory particularly where ignorant labor is employed. There is possibly some advantage in having one 2½-gallon extinguisher at the compress tower.

YARD HYDRANT SYSTEM.

An adequate system of yard hydrants fully equipped and maintained is one of the greatest assets of a warehouse plant. Unfortunately, the value of the yard hydrant installation is often impaired because the hydrants are not located properly or because the equipment has deteriorated. Hydrants should be housed with all equipment ready for use as shown in figure 7.

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heavier solution and the purpose of the treatment will be defeated. The data given for calcium chloride is based upon the chemically fused product generally used for refrigeration purposes. The tables are adapted from those given in Van Nostrand's Chemical Annual.

Treatment of water with sodium chloride, or common salt.

Sodium chloride per gallon solution.	Freezing point.		Specific gravity at 59° F., 15° C.	Weight of solution per gallon.	Density at 59° F., 15° C.
	Fahrenheit.	Centigrade.			
	°	°			°*B.*
0.44 pound, or 7 ounces	+25.4	−3.7	1.037	8.7	5.2
0.9 pound, or 15 ounces	+18.6	− 7.4	1.073	9.0	9.9
1.22 pounds, or 1 pound 4 ounces	+12.2	−11.0	1.1115	9.3	14.5
1.92 pounds, or 1 pound 15 ounces	+ 6.9	−13.9	1.150	9.6	19.0
2.5 pounds, or 2 pounds 8 ounces	+ 1.0	−17.2	1.191	9.9	23.3

Treatment of water with calcium chloride (fused 75 per cent $CaCl_2$).

Amount calcium chloride per gallon of solution.	Freezing point.		Specific gravity at 68° F., 20° C.	Weight of solution per gallon.	Density at 68° F., 20° C.
	Fahrenheit.	Centigrade.			
	°	°			°*B.*
1.46 pounds, or 1 pound 7 ounces	+18.0	− 7.8	1.1	9.2	13.0
1.83 pounds, or 1 pound 13 ounces	+12.5	−10.8	1.125	9.4	16.0
2.20 pounds, or 2 pounds 3 ounces	+ 6.5	−14.2	1.15	9.6	19.0
2.59 pounds, or 2 pounds 10 ounces	− 2.0	−18.9	1.175	9.8	21.3
2.99 pounds, or 3 pounds	−12.5	−24.7	1.2	10.0	24.0

Hose houses have been standardized fully by the insurance boards, from whom complete drawings and specification may be obtained. The general requirements are that each hydrant should be equipped with 100 feet of hose attached to hydrant and nozzle and an additional 100 feet coiled on the shelf; there should be one additional play pipe holder, four spanner wrenches, and one heavy mill lantern and two axes; unless the hydrant is controlled by a large hand wheel, there should be a wrench always attached and a spare wrench at hand. Hydrants should be frost proof and two or three way—that is, they should have two or three outlets. It is desirable that the outlets be equipped with gate valves. If the warehouse is located in or near a city the hose couplings should have the same thread as that used by the city fire department or else adapters—coupling with threads to fit the city connection on one end and the regular thread on the other end—should be provided. The play pipe referred to should be a smooth copper or brass tapered tube, 30 inches long, wound and painted. It should terminate with a 1⅛-inch nozzle. The hose should be 2½-inch cotton, rubber lined. Its durability is improved by running water through it several times a year. When this is done care should be taken to see that the cotton fabric is well dried before the hose is put away.

The subject of standardization of hydrant and hose threads is of great importance and lack of standardization has caused serious fire losses. Notable among such cases is that of the cotton fire of Augusta, Ga., in 1916, when fire forces with hose were sent from Waynesboro, (32 miles), from Macon (125 miles), and from Atlanta (171 miles), all to find themselves unable to use any of their hose because the threads did not fit the hydrants at Augusta. The estimated property loss was over $4,000,000. It is sometimes the case that city threads are not standard and therefore should be changed. In such instances it will be well for the new warehouse equipment to conform to the "National Standard" and be equipped with "adapters" during the time the city equipment is not standard.

The hydrants should be on mains of not less than 6-inch diameter with supply connection of equal size, or greater as the size of the plant demands. The mains should be arranged to form a loop system divided into sections so that the forced abandonment of a flowing hydrant would not dissipate the pressure or supply of water. This also allows repairs to be made with a minimum of interference to the system. Hydrants and valves should not be located nearer the building than 50 feet as the heat from fire might otherwise make their use impossible. If the court between buildings has to be less than 100 feet (a deplorable condition) or

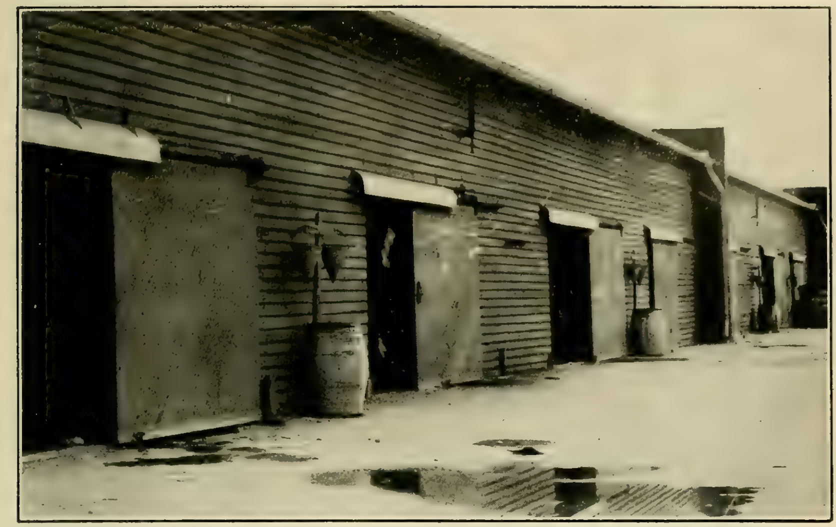


FIG. 1.—A "WOOD-END" WALL FULLY PROTECTED BY EAVES SPRINKLERS.

Note also the location of water barrels and fire pails ready for use.

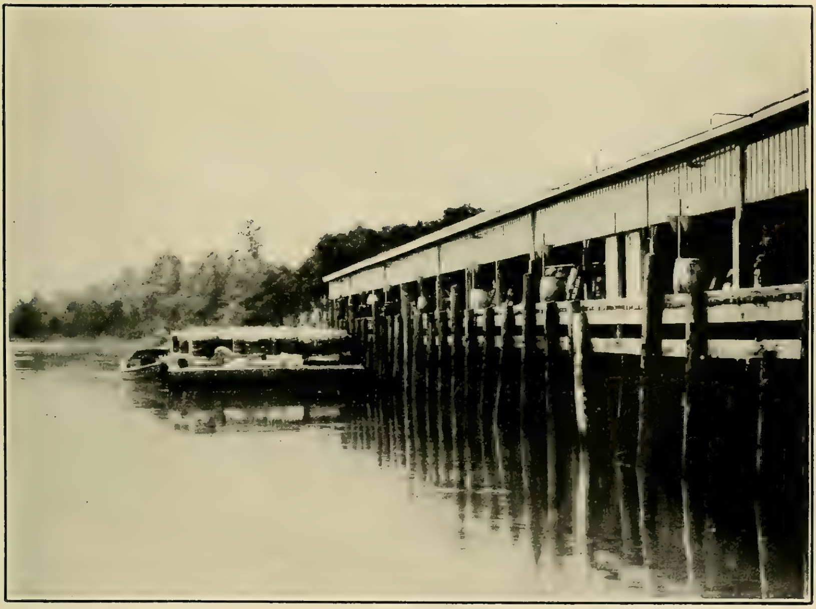
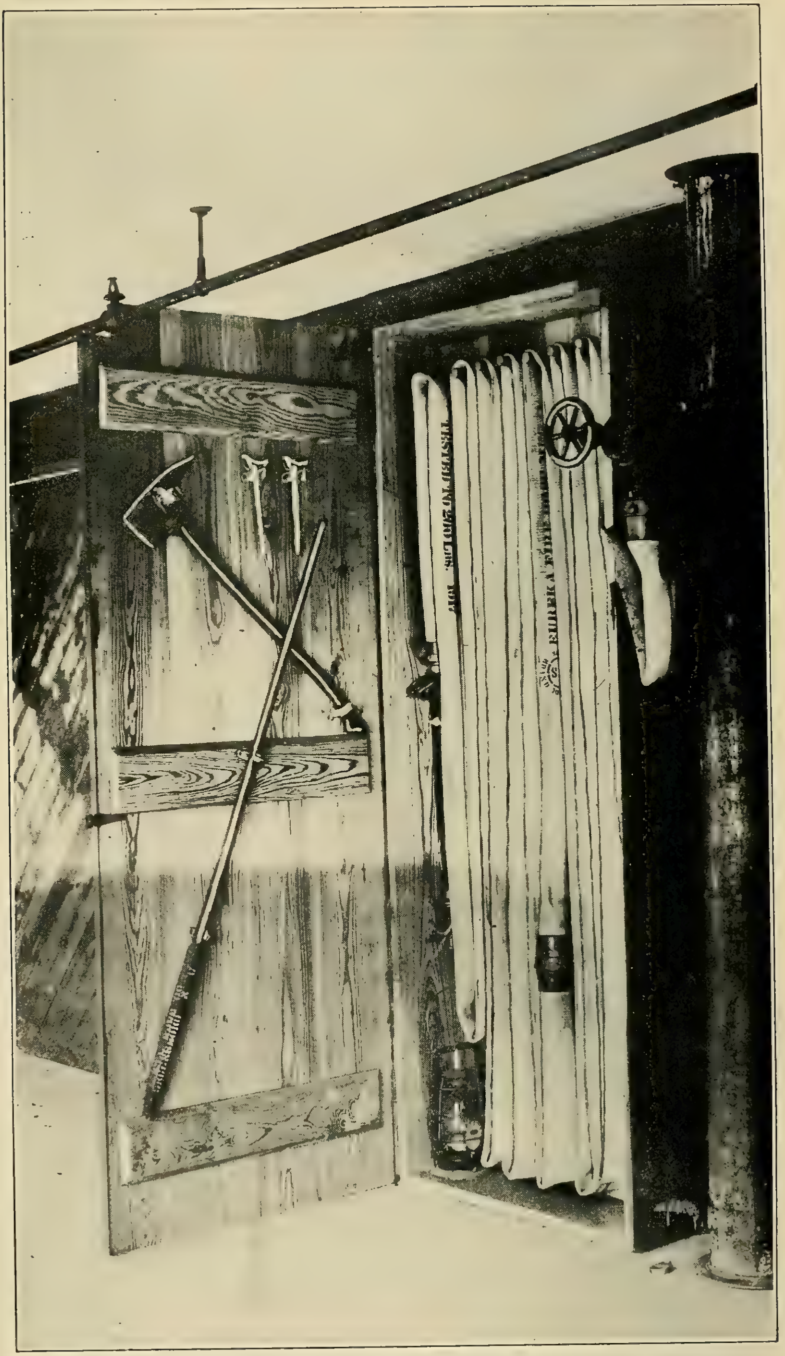


FIG. 2.—A RIVER WHARF OF INEXPENSIVE CONSTRUCTION.

The entire area is covered and fully protected by automatic sprinkler equipment.



A WELL-EQUIPPED HOSE RACK AND STANDPIPE FOR USE ON PLATFORMS OF UPPER STORIES.

if tracks conflict with the preferred hydrant location, the hydrants should be staggered, that is, alternate hydrants should be placed 50 feet or more from the building or storage area considered, the remaining hydrants being similarly located with reference to the other building. The hydrants should be spaced at intervals of from 150 to 250 feet, depending on the risk. The arrangement desirable for some conditions is shown in Plate II. It may be seen that hydrants are placed in the center of the clear space of 100 feet, except that where tracks interfere the hydrants are placed alternately on either side. The entire proposed system of hydrant protection should be approved by the insurance rating bureau and insurance concessions should be arranged before the work is begun.

The effectiveness of hydrant equipment depends largely on the volume and pressure (under flow) of the water supply. This is discussed in some detail under the head of "Water supply," but it may be stated here that the minimum requirements for pressure should be such that two streams—from any hydrant—flowing through 100 feet of hose and a $1\frac{1}{8}$-inch nozzle will discharge 250 gallons per minute each. Good working pressure is from 60 to 80 pounds.

STANDPIPE SYSTEM.

Warehouses of more than three stories in height or having the third floor more than 30 feet above the ground should be equipped with a system of standpipes. This is a valuable adjunct to the hydrant system under such conditions. Standpipes should be located in such manner as to be accessible during fire and provide available streams for any compartment. The distance between the risers should be governed by the proportions of the compartment and the amount of hose provided. In nearly all cases standpipes should extend through platforms and provide an outlet for each platform.

Water connections may be such as to keep the pipes filled with water or the connection may be such that water is admitted only when needed. The first, or wet system, should be used whenever possible, as it provides an instant supply of water. If the pipes must be kept emptied in winter it is desirable to provide mechanical control on each floor for operating a control valve protected from freezing. If this can not be accomplished there is likely to be delay in geting water to the hose in case of fire. Dry-pipe risers should be galvanized.[1]

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[1] If the wet-pipe system (with pipes filled with water to the hose valve is used, the hose valve should contain a drip outlet and be turned in such posi-

AUTOMATIC SPRINKLER SYSTEM.

The automatic sprinkler system is particularly well adapted to the cotton warehouse. There are few conditions which justify a warehouse of any reasonable size being without the sprinkler protection. Aside from the actual reduction in fire damage throughout the country by its use, the warehouse owner nearly always will find the automatic sprinkler a good investment from the standpoint of reduced cost of insurance. A recent survey of warehouse facilities, made by the Department of Agriculture, showed that out of 1,768 cotton warehouses reporting the 133 which were sprinklered had an average insurance rate of 36 cents while those not sprinklered had an average rate of $2.43 per annum per $100 valuation on contents. Moreover, the record of fires held in check or extinguished by the sprinkler system is most satisfactory. These facts give some idea both of the value of protection and saving in cost of insurance which the warehouseman may secure by sprinkler installation.

Automatic sprinkler installations are shown in Plates XVI, XXII, XXXI. The views show the sprinkler heads, or nozzles, placed so that a spray of water will be thrown over the ceiling and the cotton when a fixed temperature is reached, usually 165°. As shown, the piping is arranged and proportioned to give promptly an adequate amount of water flowing from a number of heads, provided the supply is satisfactory. These are the results which all requirements for sprinkler equipment are aimed to secure.

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tion that water leaking past the valve will not rot the hose at the connection. This is a potent source of deterioration. Also, if the pressure is likely to become very high, as from direct pumping, the riser outlet should be equipped with a relief valve which would discharge and so dissipate the water pressure in case it exceeded the safe pressure for the hose. Usually one such valve for each riser is sufficient.

Each standpipe outlet should be provided with a complete hose station, each equipped in about the same manner as the hose house previously described. An exception to this equipment is that the hose may be linen, unlined, and for most cases the two lengths of hose need be only 50 feet each. The exact amount of hose depends, of course, on the arrangement of the system and building. The size of hose usually should be the same as that for the hydrants, though frequently 1½-inch hose is satisfactory. The size of the riser, however, need not exceed 4 inches and frequently may be less, depending on the number of stories. The water supply usually should be from the hydrant system. One outlet for each floor from each riser is satisfactory for most cases. A simple hose station is shown in Plate XXXII.

Standpipe systems, like the hydrant systems, have been standardized completely. The arrangement and specifications should be decided after consultation with the insurance inspection department having supervision. In this way the warehousemen may secure such recognition of equipment as the system entitles him to.

Automatic sprinkler systems for most conditions are one of the two general types, known as the "wet" or the "dry" system. In the wet system the pipes are filled constantly with water, while in the dry system the pipes are filled with air under pressure. In this latter case the fusing of a head from fire allows the air to escape and thereby unbalances the water pressure which in turn actuates a valve which admits water to the system. This valve is known as the "dry-valve." The wet system should be used wherever there is no danger of the water in the pipes freezing in winter. Where the climate affords this danger of freezing, the dry-pipe system should be used. Some of the advantages of the wet system are that water is discharged instantly upon the fusing of a head, the possible failure of a dry-valve to open is avoided, and the cost of installation is less.

Sprinkler systems may be arranged so that the pipes are filled with water in summer and yet operated as a dry-pipe system in winter. This may be accomplished by a supply pipe or "by-pass," extending around the dry-valve so that when the "by-pass" is open, water does not flow through the dry valve. Such an arrangement is very desirable.

One of the first questions to be decided is whether the system shall be wet or dry. If in doubt, the best procedure is to get bids on both systems and also a definite expression from the insurance rating bureau having supervision, as well as to make a careful study of local temperature records for a number of winters. In some instances the "eaves sprinklers" may be connected to the main system through a gate valve and drip so that the exposed piping can be drained during cold nights. However, no chances should be taken toward having a frozen-up sprinkler system. These statements refer, of course, to unheated buildings.

Sprinkler heads, or nozzles, should be so placed that all ceiling area and goods may be reached by the spray. The protection should be extended to include all platforms on which cotton is handled. The heads should be arranged to give the best protection in consideration of the construction of the building. The various drawings previously shown indicate a suitable arrangement in several buildings. Usually there should be one line of sprinkler heads down the center of each bay (space between timbers) for bays not exceeding 12 feet in width. The spacing of the head should not exceed 12 feet in either direction and preferably should not exceed 10 feet. Sprinkler heads nearest walls should not be farther from the wall than half the spacing between heads. With these provisions met, there may be allowed one sprinkler head to not exceeding 100 square feet of floor area. However, a greater number of heads is very desirable, one head for every 80 square feet being preferred.[1]

The dry-pipe system demands the use of an air compressor for maintaining air pressure in the pipes. A hand compressor is not at all burdensome for warehouses not exceeding 10,000 bales capacity. If the pipe joints are tight the leakage of air should be so slight that the system will need to be pumped up only once a week. The pressure valve, however, should be read every day.

All valves supplying the sprinkler system should be kept open and sealed or tagged conspicuously and inspected frequently in order to insure prompt action of the sprinklers. It is well for the management to keep a record of systematic inspections. Several members of the force and all foremen should be familiar with these valves.

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[1] The position of the head with reference to the ceiling and goods is of the utmost importance. Usually the distance of the head below the ceiling should be from 3 to 10 inches, 6 or 7 inches being preferred. In the case of fire-restrictive construction, protection of the ceiling is of less importance, and the drop of the head may be increased. These requirements are appreciated when the roof contains monitors or saw-tooth skylights. In any case the sprinkler head preferably should be as much as 3 feet above the surface of cotton bales, while this distance should not be less than 18 inches, even if sprinkler heads are only 8 feet apart. Care should be taken to see that heads are not placed so close to the side of beams that the spray is obstructed.

The arrangement of piping and the size is of vital importance to effective sprinkler operation. If pipes are too small in proportion to their length and to the number of heads supplied, the efficiency of the equipment is vitally impaired in case of a number of heads opening, as this results in a marked reduction in pressure and volume of water delivered.

This suggests the importance of a suitable location for the sprinkler "riser" which supplies water to the system. A comparison of the plans previously illustrated will show that for compartments 50 by 100 feet the riser is placed in a corner; for compartments which are 100 feet square the riser should be at the center of one side, while for compartments less than 100 feet in one dimension and greater than 100 feet in the other, the riser should be located at the center of the long wall; and if the compartment is greater than 100 feet in both dimensions, the riser should be at the center of the area, as shown by the photograph in Plate XXII, figure 2. It is desirable that the riser always be placed at the center of the area, but there are frequently practical difficulties involved. For example, in a story of 8½ feet the clear height below beams is usually only 7 feet or less; obviously the lateral supply pipe extending from the riser and at right angles to the beams (between which the branch lines carrying sprinkler heads are located) would have to be so low as to seriously obstruct truckers—hence the advantage of having this supply line next to a wall. On the other hand, there are instances where alternate beams are carried by a line of girders, in which case it may be best to place the supply line under the girders in order that the branch lines may be kept well up between the beams. In the case of reinforced concrete girders of very great depth it is sometimes desirable to provide pipe thimbles (holes) in the girders

The effectiveness of the sprinkler system depends largely upon the immediate availability of water under adequate pressure. A sprinkler supplied with water at 10 pounds pressure will discharge about 20 gallons of water per minute, while with the pressure at 60 pounds the head will discharge nearly 50 gallons per minute and distribute the water better. The pressure adopted should be governed by the resulting pressure under flow considered with the cost under the given conditions. For example, gravity tanks, generally used as a primary supply, should have such elevation that the bottom of the tank will be at least 30 feet above the highest sprinkler head. This subject is discussed further under the head of "water supply."

The automatic alarm service which the sprinkler system affords is a most valuable feature. These alarm gongs may be controlled

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in order that the supply line may be run through them, but this arrangement should be avoided if possible.

All pipe lines should be supported securely and in such manner as to secure a permanent grade for drainage of the system. Sprinkler heads always should be turned up.

In the arrangement of piping and heads for reinforced concrete buildings of several stories there will be found frequently a great advantage in the use of a "flat-slab" system of construction in that fewer sprinkler heads may be required or a reduction in story height may be permissible. In any type of construction a slight increase in cost of the building, due to spacing or arrangement of beams, etc., may be more than justified by a saving in cost of sprinkler equipment. Therefore, it is well to plan always for the possible use of sprinkler equipment even though it can not be installed immediately.

It is of primary importance that there be a proper arrangement of supply lines and control valves. It is essential that the control valve be so located as to be accessible during fire for conditions may arise making it desirable to cut off the supply of a section, as, for example, if the roof of one compartment collapsed; otherwise the water supply and pressure may be dissipated to such an extent as to impair the operation of the whole system. Therefore, it is desirable that each compartment system be controlled by a post indicator gate valve (a valve which registers whether open or closed) located if possible 40 feet or more from the building. There should be no valve inside the compartment as they may be closed inadvertently. In the case of a dry pipe system one dry valve may be used for the equivalent to five single-story compartments each 50 feet by 100 feet. In such case it is desirable that the dry valve be located 50 feet from the building, with the supply from the dry valve controlled by a post indicator valve. On the discharge side of the dry valve, and beyond the dry-valve by-pass, mains should be taken off to each compartment, each main controlled by a separate gate valve, preferably of the outside screw and yoke type. These valves, with the exception of the post indicator supply valve, should be located, preferably, in the pit with the dry valve. Some plants provide the dry valve near or inside of a compartment, thus affecting a considerable saving in piping. Such an arrangement is satisfactory, but is not so good as that previously described.

When the dry valve is used, it should be placed in a frost-proof pit underground or in an insulated frost-proof room. It is an easy matter to prevent freezing of the valve at locations in the cotton belt, but farther north a small amount of heat must be provided.

by a water motor which operates the alarm when there is movement of water flowing through the pipes; or the alarm may be operated by electricity, the operation being caused by a flow of water. The water motor alarm is generally used for the cotton warehouse. There should be a separate alarm for each branch main, which usually means a separate alarm for each compartment. (See the discussion of signaling systems.)[1]

The warehouseman who is considering sprinkler equipment would do well to employ an engineer to handle the contract and negotiate with the insurance companies. The warehouseman, however, may be able to get information as to the cost of such equipment by applying to the sprinkler company's engineers, but he should secure insurance concessions before letting the contract in order that he may know what saving and increased revenue will be affected. Some plants can pay for sprinkler equipment by resulting insurance savings of a few years.

WATER SUPPLY.

The water supply available or which may be secured at a reasonable cost frequently limits the fire protection of small warehouses. Under most conditions a warehouse should not be constructed unless a reasonable supply of water can be provided.

Water supplies are considered as "primary" and "secondary;" the first being the source from which water is furnished automatically to the sprinkler or hydrant systems, while the secondary supply is the means for supplementing the first. The secondary supply may be controlled automatically or by hand.

The usual supply of water for the warehouse is the city main connection and a gravity tank, the tank, used as a primary supply, being filled from the city mains. The tank gives a constant head of water in case the city supply is interrupted, so it is of greatest importance that the tank be kept full. For the warehouse plant of ordinary size such a supply is all that should be required provided the city supply itself is satisfactory. Fairly good protection is afforded by the city connection alone, the objection to this being that water may be cut off at times for work on mains.

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[1] The detailed requirements of the sprinkler system have been so completely worked out by the National Board of Fire Underwriters that it is undesirable to have duplication of these specifications here. Moreover the sprinkler system involves the use of various valves and other equipment which must be tested by engineers such as the service supplied by the Underwriters's Laboratories.

For warehouse plants maintaining a central watch station, or for other extensive plants, the automatic supervision service should prove of value. This consists of a system of electric signals which will give an alarm and register at the watch office any interference with valves, water supply, pressure, flow of water or low air pressure of the dry system.

If the warehouse plant is very large and a satisfactory city supply is not available, the gravity tank should be used as the primary supply and suitable pumps with abundant water available should constitute the secondary supply. These supplementary pumps are always desirable for a very large plant. With the combination of tank and pumps the system is complete in itself, as the pumps may be used for filling the tanks, though these may be filled from the city supply.[1]

The water pressure maintained for hydrant protection should be from 50 to 80 pounds, the minimum being that which will give two standard hose streams as previously described. The actual delivery of water is made the minimum test because the actual pressure under flow may be very much less than that normally registered by the pressure gauge, because of the length, small size, or bad condition of the yard piping. The pressure used for the sprinkler system may be that used for the hydrant system, the same supply lines being used for both. If a low gravity tank constitutes the sprinkler supply, the bottom of this tank should be at least 30 feet above the highest sprinkler heads. In many instances the gravity tank is from 75 to 100 feet high. Frequently an elevation of the ground can be used to advantage in affecting a saving in height of the tank tower.

The yard piping system should always be arranged as a "loop system" so that water from any source can be delivered to any point without undue friction loss. The system should be divided into sections by post indicator gate valves in order that changes or repairs may be made in any part of the line without putting the entire system out of use. Repairs and changes, when necessary, should be made with as little interruption to the service as possible. The loop and section arrangement is of great value in case of a severe fire when open hydrants may have to be abandoned as such an arrangement is of value in conserving the water supply and pressure. sure.

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[1] Each source of water supply should be protected against every other supply by check valves. The need for this is apparent from the following illustrations: Suppose a gravity tank primary supply is connected with a city main and the city connection is not protected by a check valve, the drainage of this part of the city main would drain the tank also and leave no water supply. Again, if the tank and pump supplies are used the tank is at an elevation designed to give the pressure desired for the sprinkler system with dependence placed on the pumps for hydrant pressure, the desired increased pressure and supply from the pumps when in operation will be dissipated by overflowing of the tank unless it is protected by a check valve. Or if the tank is not protected against greater city pressure the same overflowing and loss of pressure would result. Check valves to protect tanks should always have a by-pass around them in order that water may be forced through the by-pass into the tank. The by-pass valve should be of the post-indicator gate type.

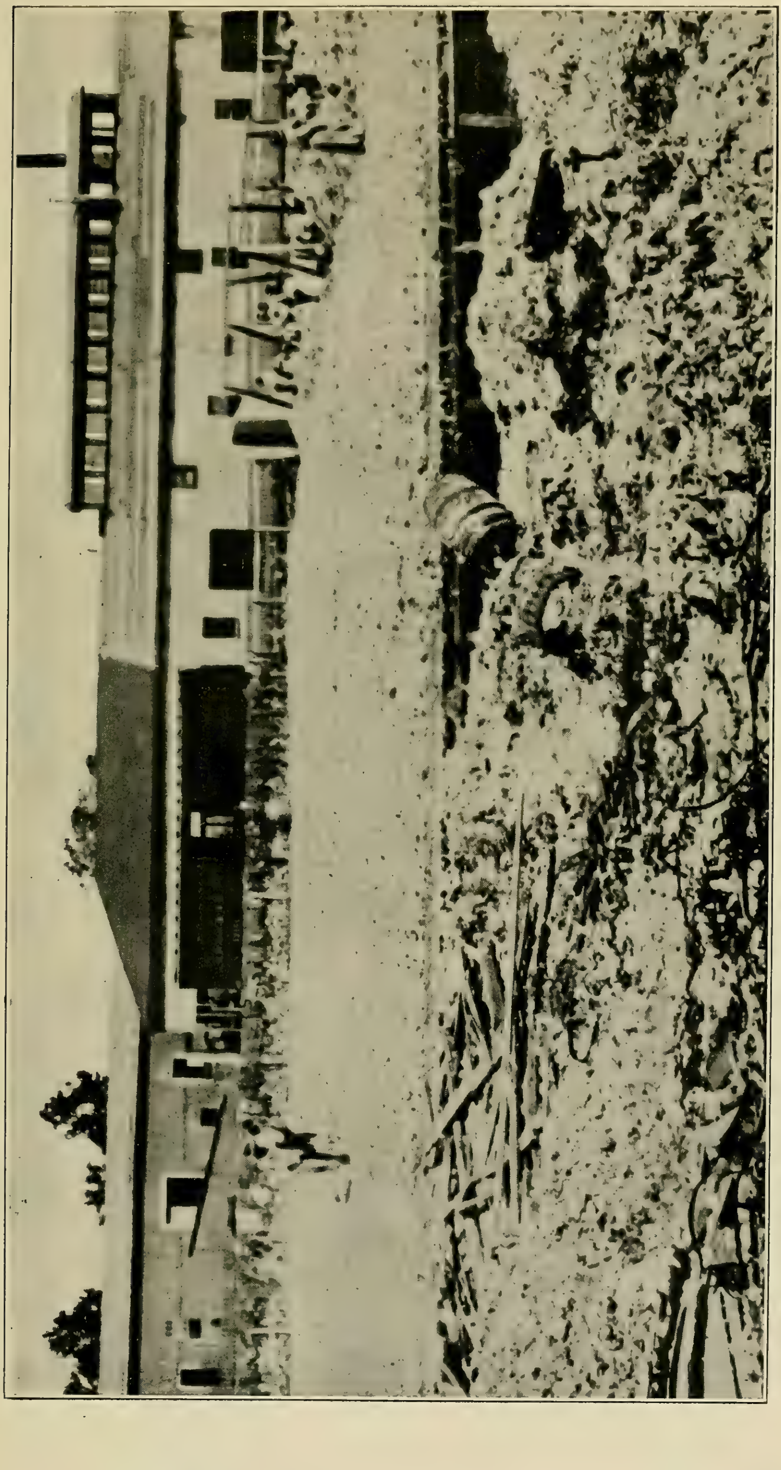
Fire pumps include three preferred types—the duplex Underwriter's steam pump, the centrifugal pump (usually electrically driven), and the rotary pump (usually mechanically driven). The available power often determines the type of pump used. If it is practicable to keep up constant steam pressure, the steam pump should be used, while if steam is not available throughout the season the steam pump should be supplemented by an electrically-driven centrifugal pump, usually of the double-stage type. The rotary pump meets such conditions as are furnished by water power as the available drive. Generally speaking, the steam power is the most reliable. If electric power is relied on entirely there should be two supplies of current if possible. Pumps should deliver water at 100 pounds pressure. All pumps should be kept in the best condition and run for a few minutes every week. Main valves should be kept open and suction lines and intake strainer kept clean.

Gravity tanks are usually of steel, as it makes a durable tank which is economical for most conditions. If a natural elevation of the ground can be used so as to reduce the height of the tower, tanks of reinforced concrete are excellent, the economy of this type of tank depending largely upon the local cost of the materials and whether or not other concrete work is being done at the time. The capacity of the tank should not be stinted as a large supply is very desirable. Moreover, the cost of the tank should be less in proportion as the capacity increases. Again, the extra capacity may permit a future extension of the plant without the necessity of an additional tank. Wooden tanks are sometimes used but their liability to decay makes their use inadvisable for most conditions. Gauges for registering the amount of water in the tank always should be supplied.

Freezing of water in tanks and risers during winter must be guarded against. For the greater part of the cotton belt the only precaution necessary is that the tank riser pipe be insulated. A wooden boxing packed with dry sawdust and made water-tight frequently will be found sufficient. Colder climates demand that the water be kept heated slightly during cold weather. This is accomplished by means of a special tank heater arranged and connected so that there is a constant circulation and even heating of this water in both tank and riser. Heat may be supplied by either steam or an independent hot-water heater. There are a number of different makes of tank heaters on the market.

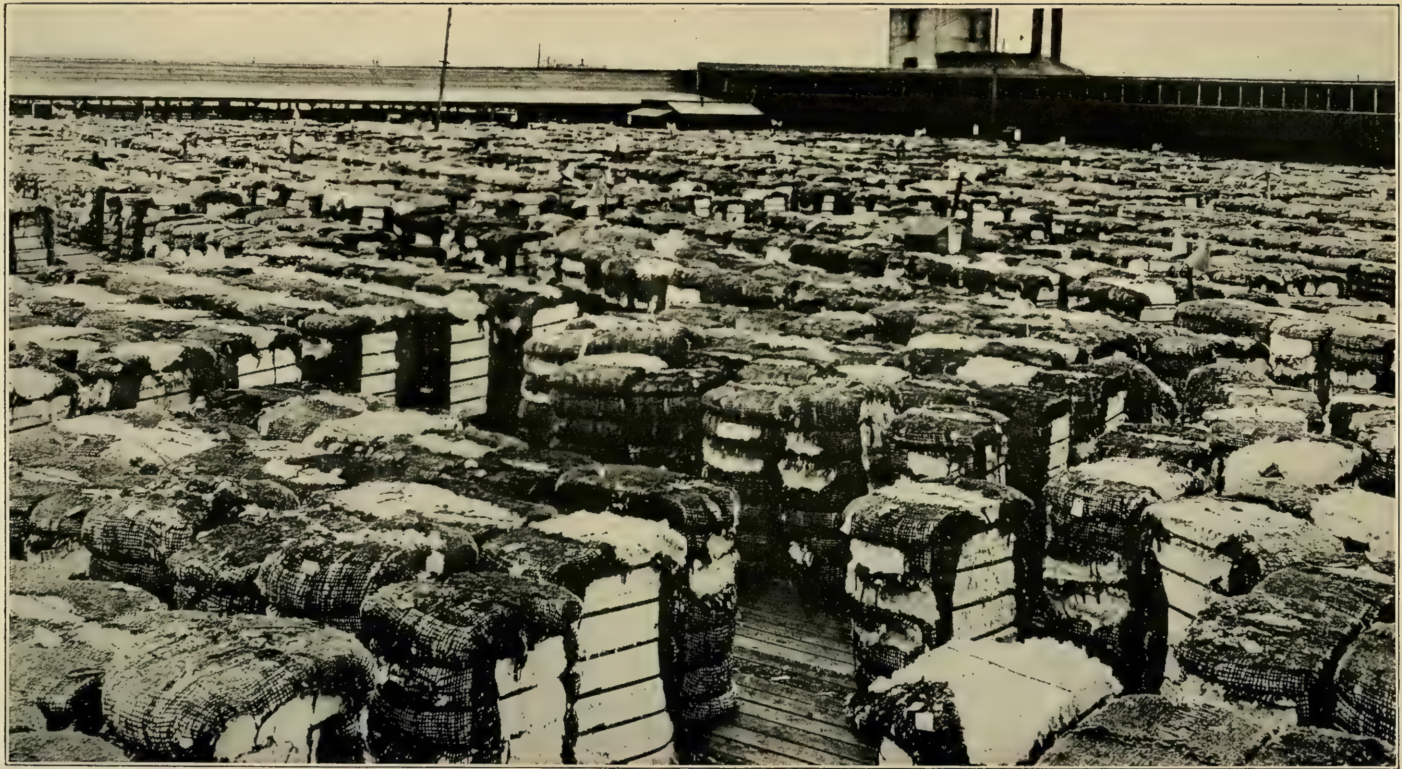
The amount of water supply for the private system has not been stated, because this is really a matter of judgment and should be

PLATE XXXIII.



CONDITIONING COTTON WITH ALL SURROUNDINGS READY TO CONTRIBUTE TO A CONFLAGRATION.

Note the wood platform covered with cotton and extending directly to the railway siding and buildings.



THOUSANDS OF BALES OF COTTON AND THE COMPRESS PLANT ALL SUBJECT TO A SINGLE FIRE.

When such an amount of cotton must be assembled in the open, it should be divided into lots of from 3,000 to 5,000 bales with these lots separated by two hundred feet clear space.

decided after consideration of the exact character of the supplies and the general hazard. Obviously, a fire-resistive plant well sprinklered would not need so great a supply of water as a plant of the semislow-burning, or wood-end type. While there are general rules in use for determining the supply required, it is not thought best to enter into a detailed discussion of them. The warehousemen should govern this question in detail with the insurance rating bureau having supervision before placing a contract for equipment.

SIGNALING SYSTEMS.

Signaling systems include any devices, both manual and automatic, for transmitting an alarm of fire.

The automatic sprinkler alarm referred to under that heading is especially well adapted to the cotton warehouse, and, generally, is the only such device that is required. Where this includes the electric type of alarm (either alone or in addition to the water motor alarm) the connection should be extended to the city fire department if such is available. This may be done by making a connection with the nearest city alarm box, though it is desirable that the connection be extended direct to the city fire department headquarters. This connection is valuable even in very small towns. A system of fire-alarm boxes is needed for large warehouses, but the expense is not justified for the plant of average size.

There are various automatic signaling systems on the market, but for the cotton warehouse the automatic sprinkler fulfills this service with entire satisfaction.

It is worthy of note that any electric signaling system, including the electric sprinkler alarm, may be used to close automatic fire doors when they are equipped with an electric release box.

PROTECTION AGAINST LIGHTNING.

Warehouses located in rural districts or in a locality subject to severe electrical storms should be protected against this source of fire, by adequate rodding. The "iron-clad" buildings are subject to the least hazard in this respect if the metal covering is thoroughly grounded. This may be accomplished by the gutter conductors where these discharge into cast-iron drain pipes extending well below the surface and into soil which is constantly moist.[1]

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[1] Information on this subject, together with specifications for various types of installation, is contained in Farmers' Bulletin No. 842: Modern Methods of Protection Against Lightning, which may be obtained free of charge from the Division of Publication, U. S. Department of Agriculture. See also Suggestions for Protection Against Lightning recommended by the National Fire Protection Association.

WATCHMAN SERVICE.

Watchman service is an asset of variable value. The reliable service of one or more alert and able-bodied watchmen should be provided for plants of any considerable size. This is a form of protection which may be worth very much or nothing, depending on the character and duties of the watchmen. The regular tour of the watchman should be assured by well-distributed watch stations and a recording clock. The watch stations should be so distributed that in visiting them in sequence every part of the plant can be viewed. The equipment may consist of a portable watchman's clock carried by the watchman. The clock provides a specially ruled paper dial which is punched by the keys contained in and securely attached to the different watch station boxes. The paper dial is not otherwise accessible to the watchman. These paper disks are removed daily and filed in the office, thus effecting a record of the time at which the stations were visited. This form of equipment and service is adapted to most warehouses.

Large plants should be equipped with the central station watch service. In this case the recording clock is located at the watch office and the record of reports is punched on a paper tape. The watch stations provide a signaling mechanism electrically connected to the central station. When the watchman turns a key the number of this station together with the hour is registered upon the tape record at the watch office. If the signal is not given at or soon after the schedule time some one from the office is sent to the box to investigate the delinquency. In case any watchman on his rounds discovers fire, he uses this same station for turning in an alarm, which is transmitted to and automatically registered at the central watch office. The wachman then gives his attention to the fire, and is assured of prompt assistance directed from the watch office, while the other watchmen not otherwise directed continue their rounds.

Any system of watch service should be based upon a regular schedule, or tour, for the watchman, prepared by some one who has a knowledge of fire protective service. Insurance bureaus are glad to render this assistance. The interval set between visits of the watchman depends upon the general hazard, but should not exceed half an hour.

PRIVATE FIRE BRIGADE.

Organization for systematic team work in dealing with a fire should not be neglected. Years may pass without even an alarm, but this is not a good reason for not training employees of the plant as a private fire brigade. Each individual should understand fully the use of all fire protective equipment and the proper procedure in case of fire. Some firms have found it an advantage to pay men on the fire team a small bonus. For an ordinary business it is necessary to have all the force on the teams, while for a large plant the selection of men for the work may be such as to make the place sought after by the employees. The essential features are that the men be drilled sufficiently and be paid an amount that will make them feel that the work is of importance. It may be well to make this payment monthly, and separate from the regular wages, in order that it may be recognized as a distinct bonus for extra work. The organization of the fire brigade should be along military lines with distinct recognition of authority. The details of course, must be suited to the size of the plant. Valuable suggestions for the organization may be obtained from the National Board of Fire Underwriters, New York City, from the National Fire Protection Association, Boston, Mass., Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass., or insurance companies. These publications may be secured upon request.

PRECAUTIONS AGAINST FIRE.

Even though construction and fire protective equipment is the best there remains the need for careful administration on the part of the management. The first requisite is that responsibility be fixed upon some one individual as to proper upkeep and orderliness of the whole plant.

All buildings should be kept in good repair, giving special attention to doors, roof openings, and fire breaks in platforms and sheds.

Water barrels and pails should be kept well filled, and in winter water should be treated to prevent freezing. All sources of water supply must be under observation that the tanks may be kept filled, pumps in good order, power maintained, and valves properly set. All mechanical equipment must be tested frequently; the hose should be tested occasionally under full-water pressure, then properly dried and coiled on the racks.

The management should see that the automatic sprinkler system is in good order, taking care that sprinkler heads are not "loaded" by a coating of whitewash or paint, that there are no valves closed, and, in the case of a dry-pipe system, that there is no water columning of the dry valve—due to excess water leaking past it and into the riser—and that the valve is in good working order. Eaves sprinklers on a wet-pipe system must be drained in cold weather. A number of extra sprinkler heads facilitate ready repairs.

All water supply valves should be open and sealed or strapped. The strap should be secured with a padlock so that the strap can be cut in an emergency but will not be tampered with ordinarily. Permission for closing a valve must be obtained from the person responsible for fire protection whenever this is possible. In any case the closed valve should be tagged conspicuously and a notice of the fact kept filed in the office during the entire time such valve is closed, in so far as this is practicable. Never have both sources of water supply cut off overnight; when making repairs, provide a temporary connection.

Fire doors should be closed at night and when not in use. There should be occasional tests of sensitive closing devices for fire doors and examination to see that fusible links are not painted or whitewashed.

Oily waste should not be allowed to accumulate, as it is a potent source of fire. It should be placed in a closed metal can kept near the press for such waste. There should be no loose cotton on floors or platforms. Conspicuous signs reading "No smoking" must be posted and the order strictly enforced. No loose matches may be permitted about the warehouses or premises. The premises must be kept cleared of dry grass, weeds, and all kinds of loose rubbish. If buildings or platforms are elevated, the space under them should be closed in to prevent such accumulations under them.

The management should avoid leaving cotton exposed overnight as far as possible. When storage in open yards is unavoidable, the bales should be separated into units not exceeding 3,000 to 5,000 bales with a clear space of 200 feet or more between such units. The use of fire walls for dividing such areas is of little value unless the area is covered by a noninflammable roof as fire brands and sparks will be blown over the wall.

Employees should follow up passing locomotives near areas of unprotected cotton to see that no sparks have started small blazes. All ashes which are removed from boilers or heaters should be wet thoroughly. The watch service should be checked up frequently and made very thorough.

SELECTION OF THE WAREHOUSE DESIGN.

Selection of the design, type of construction, and forms of fire protection for the warehouse must be made with a knowledge of the business conditions existing and to be anticipated. This involves the answer to five questions: (1) During what portion of the year will the warehouse normally be filled to capacity and during what portion of the year will the capacity be only partially utilized and to what extent? (2) Will the deposits of cotton be withdrawn in large or small lots—by individual bale orders or in solid blocks? (3) What will be the number of yearly "turnovers," or changes in the individual bales stored? (4) Will cotton be stored in the compressed or flat form of bale? (5) How long will the present business conditions exist and what prospect is there of a materially enlarged business?

If, in answer to question 1, it is determined that the warehouse will be filled to capacity during a few months only as is generally the case of a warehouse which stores for farmers, it is evident that a low investment cost is essential. Hence the semislow-burning type of construction should be used unless the surroundings or the size and congestion of the warehouse entail a serious fire hazard, in which case the slow-burning type of building should be adopted. If, in answer to question 2, it is found that cotton will be handled in small lots or by selection of individual bales, the cotton should not be piled, but should be stored one bale high on end, the storage arrangement being vitally connected with the cost of handling. This means that economy of investment and avoidance of overexpansion of the plant both are favorable to a building of two or three stories. The influence of question 3 will depend upon current local practice among storers of cotton. As to question 4 regarding cotton storage in flat or compressed form, this determines the amount of cotton which can be placed in a single compartment subject to one fire and hence influences the size of compartment advisable. The last question of expected future conditions must determine the planning with a view to future extension of the plant and permanency of the structures.

If the solution of question 1 indicates that the warehouse will be filled to its normal capacity for a large portion of the year, as may be the case of a warehouse storing for cotton dealers, the item of investment cost is of less importance and is superseded by the possible cost of insurance, of labor, and of depreciation charges. In such case, determining whether cotton will be handled in large or small lots, with or without regard to the characteristics of the individual bale, is of foremost importance. Coordinate with this factor is that of the number of "turnovers." Closely associated is the question of whether cotton will be stored flat or compressed. In general, the labor cost should be given the greatest consideration, because it is the only factor which increases with the volume of business—the end aimed at. Hence, piling cotton can not be tolerated, except for a small portion of the season. This means that unless cotton is stored compressed the multiple story design generally must be adopted. If cotton is stored compressed a single tier of bales on end filling a single story compartment economically proportioned will result in a value as great as should be subjected to a single possible fire. If cotton is stored uncompressed the contents of three such floors of equal area each, if sprinklered, would not be a greater hazard, even with the slow-burning type of construction.

But for all buildings of more than one story, fire-resistive construction is preferable.

The port warehouse, which handles cotton in large blocks, should not find any serious objection to piling cotton provided it is held in storage for a considerable time. The port warehouse may require a combination of building designs to meet different forms of business.

The cotton-mill warehouse requires convenience of handling to a certain degree, but it is overshadowed by the importance of the maximum of protection from fire. Hence the choice is usually between the low one-story wood-end building, if a small quantity of cotton is stored, and the multiple-story building of fire-resistive design if a large amount of cotton is kept on hand. For the mill that handles cotton waste or inferior cotton in quantity favorable consideration may be given to the wood-end building having a single high story with cotton piled.

In general, one-story buildings for small plants may be of the semi-slow-burning, or wood-end, type of construction, but for large plants or for plants having an exposure from the parallel buildings or from adjacent property the slow-burning design with openings fully protected should be used. From the standpoint of actual fire hazard, the best slow-burning construction with a tar-and-gravel roof is equally as good as the fire-resistive construction for the one-story building. However, there is a physiological advantage in the fire-resistive construction, and the depreciation charges are less. For multiple-story buildings fire-resistive construction should be used whenever possible, and always for buildings of from four to six stories in height. For buildings of less than four stories and sprinklered, slow-burning construction is fairly satisfactory, and for buildings of two stories the feasible construction is often the semi-slow burning or "wood-end."

It should be remembered in comparing the cost of timber and reinforced concrete floors that often the cost is practically the same for floors to carry heavy loads, while the timber construction is very much cheaper for floors designed for very light loads, particularly if the span, or spacing of supports, is long. Also, the flat-slab designs for reinforced concrete, while always desirable, are more economical as compared with the beams system when the slab is continuous through division fire walls, when the span is regular and not too great and when the loads to be carried are heavy. It is apparent that these considerations are closely related to the density and arrangement of bales stored.

Fire protective equipment should be considered of fundamental importance, and complete protection should be provided for all large warehouses.

APPENDIX.

STANDARD WAREHOUSE PLANS.

The following plans are given as a basis for warehouse planning. The notations on the plans are specific when they can be without causing lack of economy when the plans are applied over a wide range of country. The plans themselves permit some flexibility which may be necessary for their economical adaptation to the site.

Each drawing shows an end compartment and an intermediate compartment. Compartments may be combined in any number to a maximum of 700 feet length for a single building, unless local conditions demand a shorter length.

As pointed out in the bulletin, increased capacity above that shown for compartments may be provided by either increased area or height, with provision made for later subdividing of the compartment by an additional fire wall or an intermediate floor. The plans should be followed in detail wherever possible.

Contracts should not be let merely upon the plans shown here, as the variations permitted by the information on the drawings should be eliminated, and comprehensive specifications suited to local conditions should be made a part of such contract. Moreover, the plans and layout of the plant, including fire protection, should be submitted for approval to the insurance rating bureau having supervision in order that the owner may secure advantageous insurance rates. A competent engineer should be employed and a request for detailed drawings sent to the Bureau of Markets, United States Department of Agriculture, Washington, D. C.

The last drawing of the appendix shows a variety of arrangements for cotton storage in different floors and the number of bales which the arrangement provides for. The arrangement is based upon the liberal allowance of 30 by 48 by 56 inches for the American bale uncompressed. If the bales are compressed to ordinary density, 50 per cent more bales can be stored, or 75 per cent more if compressed to high density. Isles shown are a minimum width of 4 feet. In the case of compartments having "wood-end" walls cotton should not be stored within 4 feet of the frame wall, and hence a few less bales than indicated can be stored. The number and preferred location of water barrels required is also shown on the diagrams.

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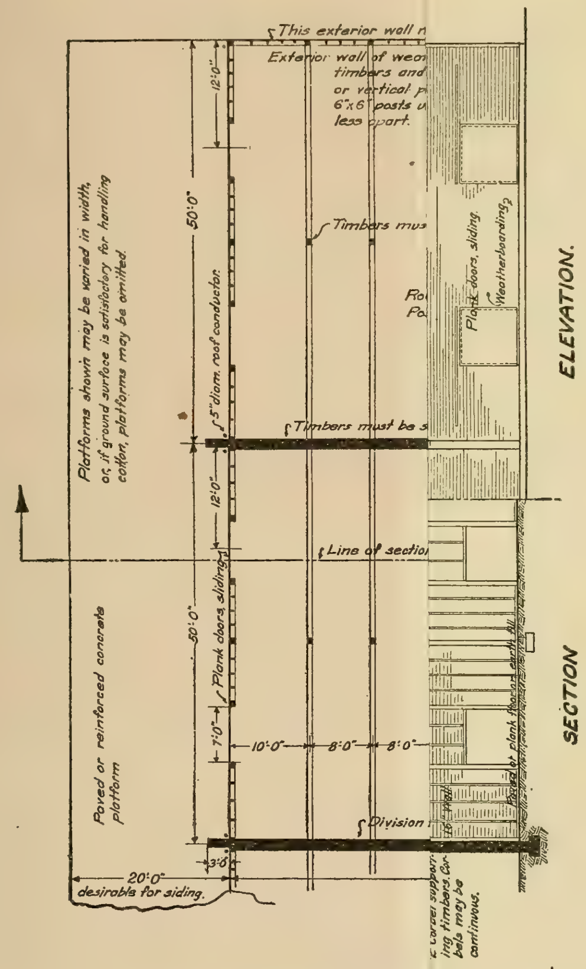
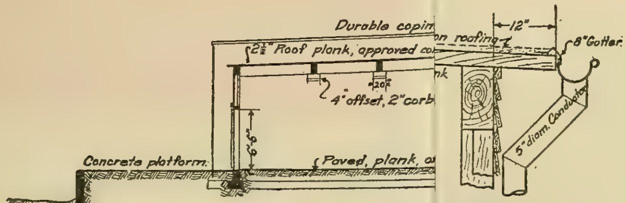
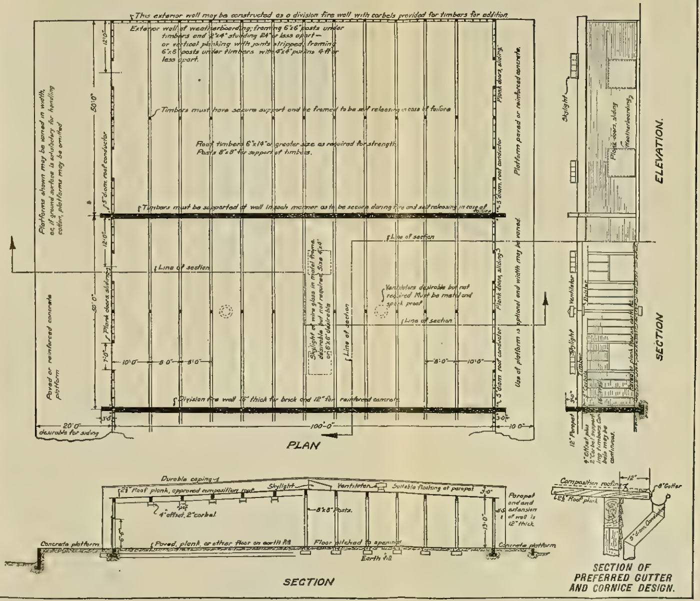




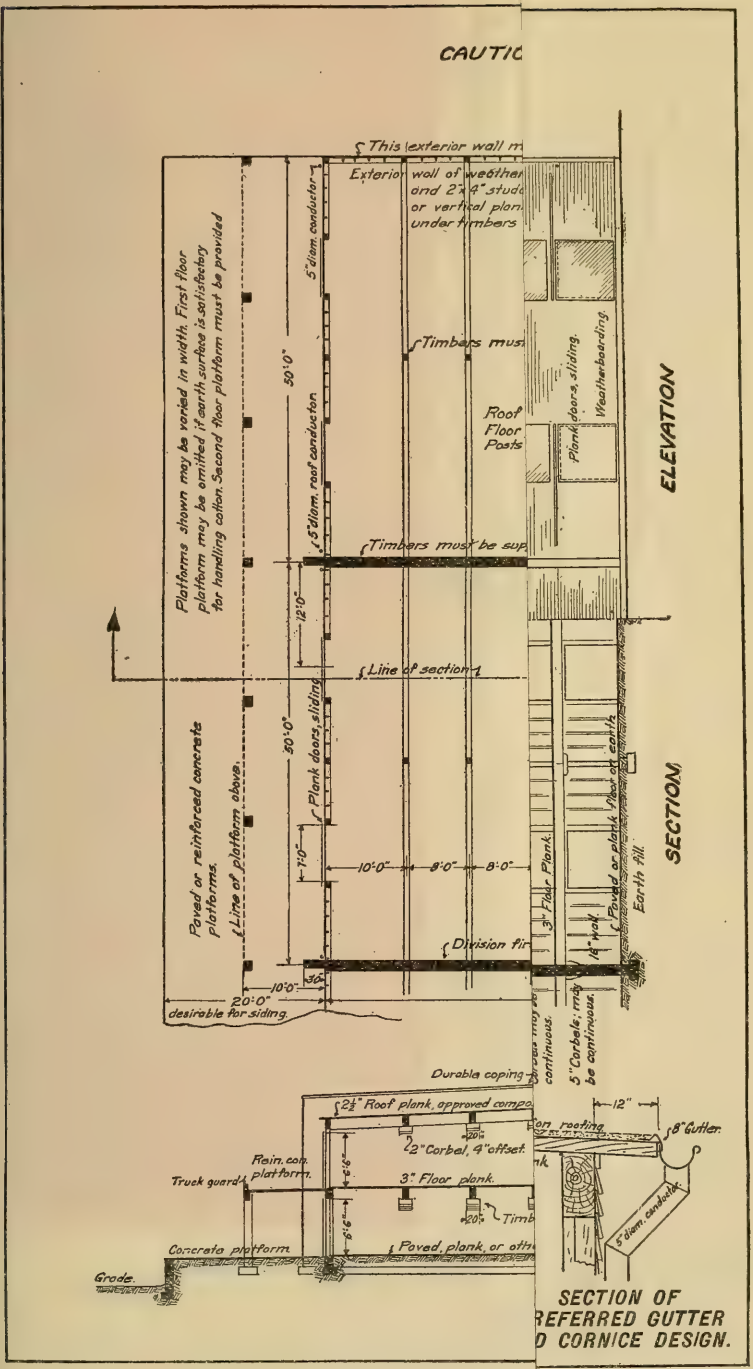
SECTION OF
FERRED GUTTER
CORNICE DESIGN.

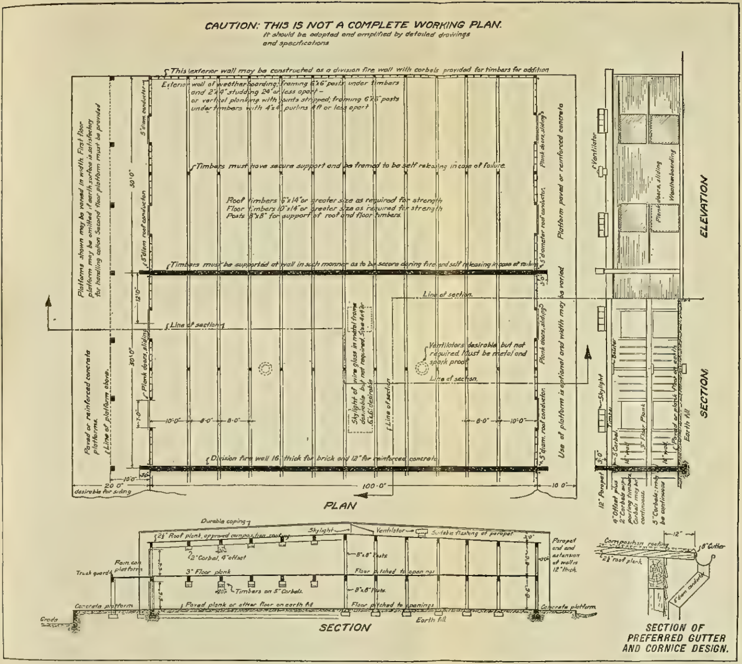


CAUTION: THIS IS NOT A COMPLETE WORKING PLAN.
It should be adapted and amplified by detailed drawings and specifications.

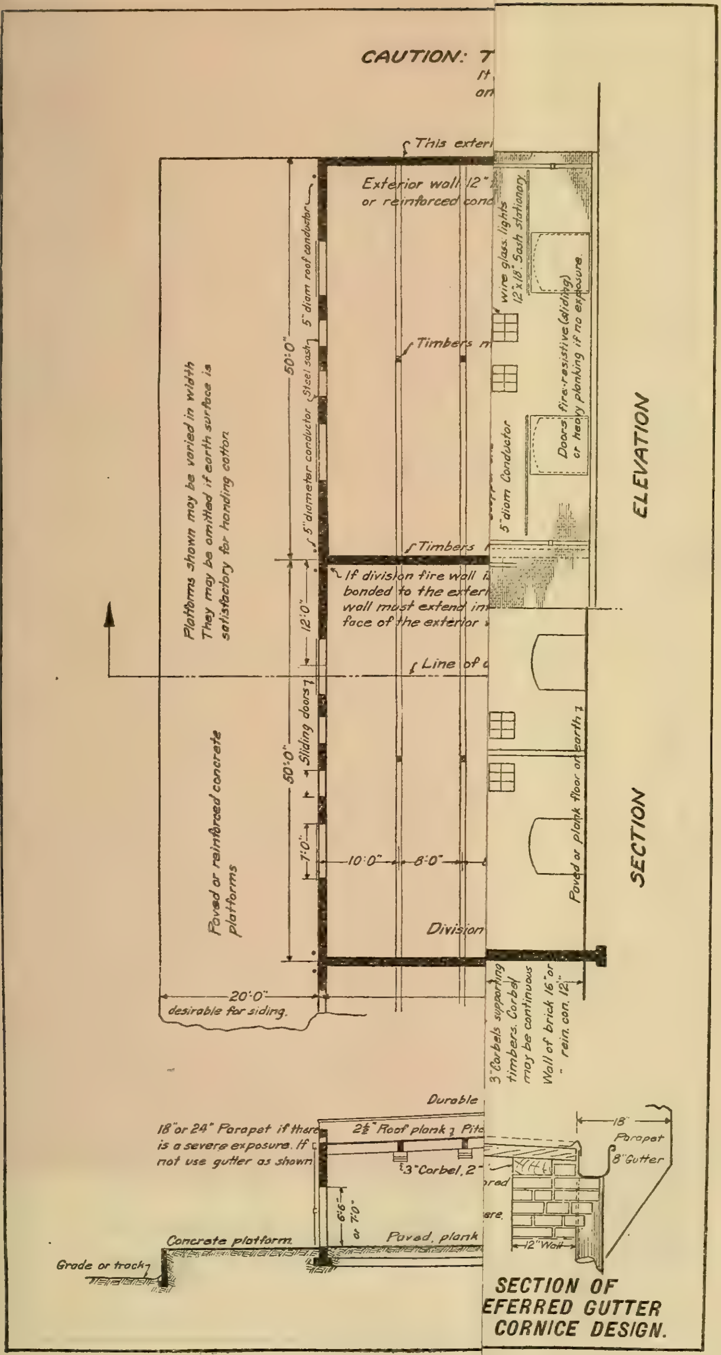
This exterior wall may be constructed as a division fire wall with corbels provided for timbers for addition.
Exterior wall of weatherboarding; framing 6"x6" posts under timbers and 2"x4" studding 24" or less apart — or vertical planking with joints stripped; framing 6"x6" posts under timbers with 4"x4" purlins 4 ft or less apart.
Timbers must have secure support and be framed to be self releasing in case of failure
Roof timbers 6"x14" or greater size as required for strength. Posts 8"x8" for support of timbers.
Timbers must be supported at wall in such manner as to be secure during fire and self releasing in case of failure
Platforms shown may be varied in width, or, if ground surface is satisfactory for handling cotton, platforms may be omitted
5" diam. roof conductor
12'0"
50'0"
Plank doors, sliding
Platform paved or reinforced concrete.
Line of section
Skylight of wire glass in metal frame, desirable but not required. Size 4'x4' or 6'x6' desirable
Ventilators desirable but not required. Must be metal and spark proof
Line of section
Use of platform is optional and width may be varied.
Paved or reinforced concrete platform
7'0"
10'0"
8'0"
8'0"
8'0"
10'0"
Division fire wall 16" thick for brick and 12" for reinforced concrete
3'0"
20'0" desirable for siding
100'0"
3'0"
10'0"
PLAN
Skylight
Plank doors, sliding
Weatherboarding
ELEVATION.
Ventilator
Skylight
SECTION
12" Parapet
3'0"
4" Offset plus 2" Corbel supporting timbers. Corbels may be continuous.
Durable coping
2½" Roof plank, approved composition roof
Skylight
Ventilator
Suitable flashing at parapet
3'0"
4" offset, 2" corbel
8"x8" Posts.
Parapet end and extension of wall is 12" thick.
13'0"
Concrete platform
Paved, plank, or other floor on earth fill
Floor pitched to openings
Concrete platform
Earth fill
SECTION
Composition roofing
12"
8" Gutter
2½" Roof plank
5" diam. Conductor
SECTION OF PREFERRED GUTTER AND CORNICE DESIGN.

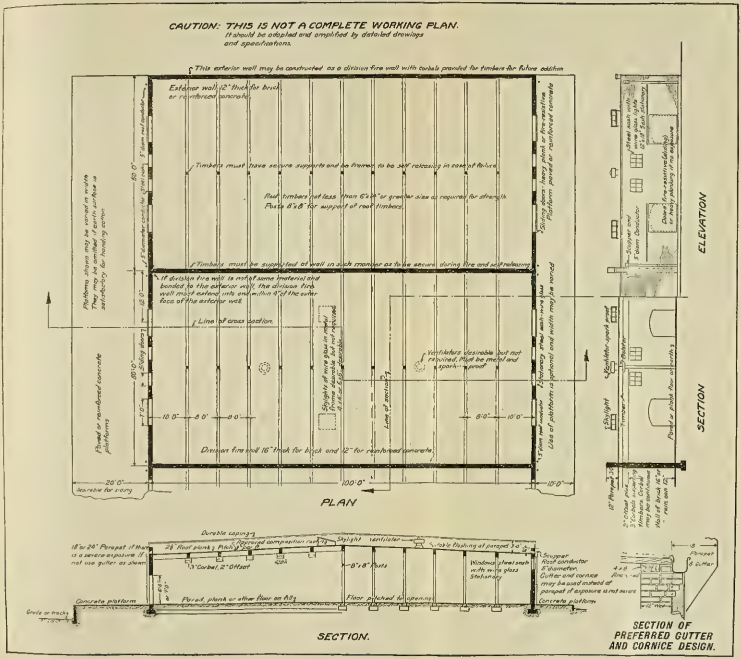
SEMISLOW-BURNING WAREHOUSE DESIGN WIA.


CAUTIC
This exterior wall m
Exterior wall of weather and 2"x4" studd or vertical plan under timbers
5" diam. conductor
50'-0"
Platforms shown may be varied in width. First floor platform may be omitted if earth surface is satisfactory for handling cotton. Second floor platform must be provided
Timbers must
Roof
Floor
Posts
Plank doors, sliding.
Weatherboarding.
ELEVATION
5" diam. roof conductor
Timbers must be sup
12'-0"
Line of section
SECTION
Paved or reinforced concrete platforms.
Line of platform above.
50'-0"
Plank doors, sliding
7'-0"
10'-0"
8'-0"
8'-0"
3" Floor Plank.
18" wall
Paved or plank floor on earth
Earth fill
Division fir
10'-0"
3'-0"
20'-0" desirable for siding.
continuous.
5" Corbels; may be continuous.
Durable coping
2½" Roof plank, approved compo
on roofing
12"
8" Gutter.
2" Corbel, 4" offset.
20"
Rein. con. platform.
Truck guard
3" Floor plank.
6'-6"
6'-6"
20"
Timb
Concrete platform
Paved, plank, or oth
Grade.
5" diam. conductor
SECTION OF
REFERRED GUTTER
D CORNICE DESIGN.


CAUTION: THIS IS NOT A COMPLETE WORKING PLAN.
It should be adopted and amplified by detailed drawings and specifications.
This exterior wall may be constructed as a division fire wall with corbels provided for timbers for addition
Exterior wall of weatherboarding; framing 6"x6" posts under timbers and 2"x4" studding 24" or less apart – or vertical planking with joints stripped; framing 6"x6" posts under timbers with 4"x4" purlins 4 ft or less apart
Timbers must have secure support and be framed to be self releasing in case of failure.
Roof timbers 6"x14" or greater size as required for strength
Floor timbers 10"x14" or greater size as required for strength
Posts 8"x8" for support of roof and floor timbers.
Timbers must be supported at wall in such manner as to be secure during fire and self releasing in case of failure
Platforms shown may be varied in width. First floor platform may be omitted if earth surface is satisfactory for handling cotton. Second floor platform must be provided
Paved or reinforced concrete platforms.
Line of platform above.
5" diam. conductor
5" diam. roof conductor
Plank doors, sliding
Line of section
Line of section.
Skylight of wire glass in metal frame desirable but not required. Size 4x4 ft. 6x6 desirable
Ventilators desirable but not required. Must be metal and spark proof.
Division fire wall 16" thick for brick and 12" for reinforced concrete
5" diameter roof conductor
Platform paved or reinforced concrete
Use of platform is optional and width may be varied
30'0"
12'0"
7'0"
10'0"
8'0"
3'0"
20'0"
desirable for siding
100'0"
10'0"
PLAN
Durable coping
2½" Roof plank, approved composition roofing
Skylight
Ventilator
Suitable flashing at parapet
2" Corbel, 4" offset
8"x8" Posts
Rain. con. platform
Truck guard
3" Floor plank
Floor pitched to openings
Timbers on 5" Corbels.
Parapet and end extension of walls 12" thick.
Concrete platform
Paved plank or other floor on earth fill
Floor pitched to openings
Concrete platform
Grade
Earth fill
SECTION
Ventilator
Plank doors, sliding
Weatherboarding
ELEVATION
Skylight
Timber
Batter
3" Floor Plank
Paved or plank floor on earth
Earth fill
5" Corbel
12" Parapet
4" Offset plus 2" Corbels supporting timbers. Corbels may be continuous.
5" Corbels; may be continuous
SECTION
Composition roofing
12"
8" Gutter
2½" roof plank
5" diam. conductor
SECTION OF PREFERRED GUTTER AND CORNICE DESIGN.

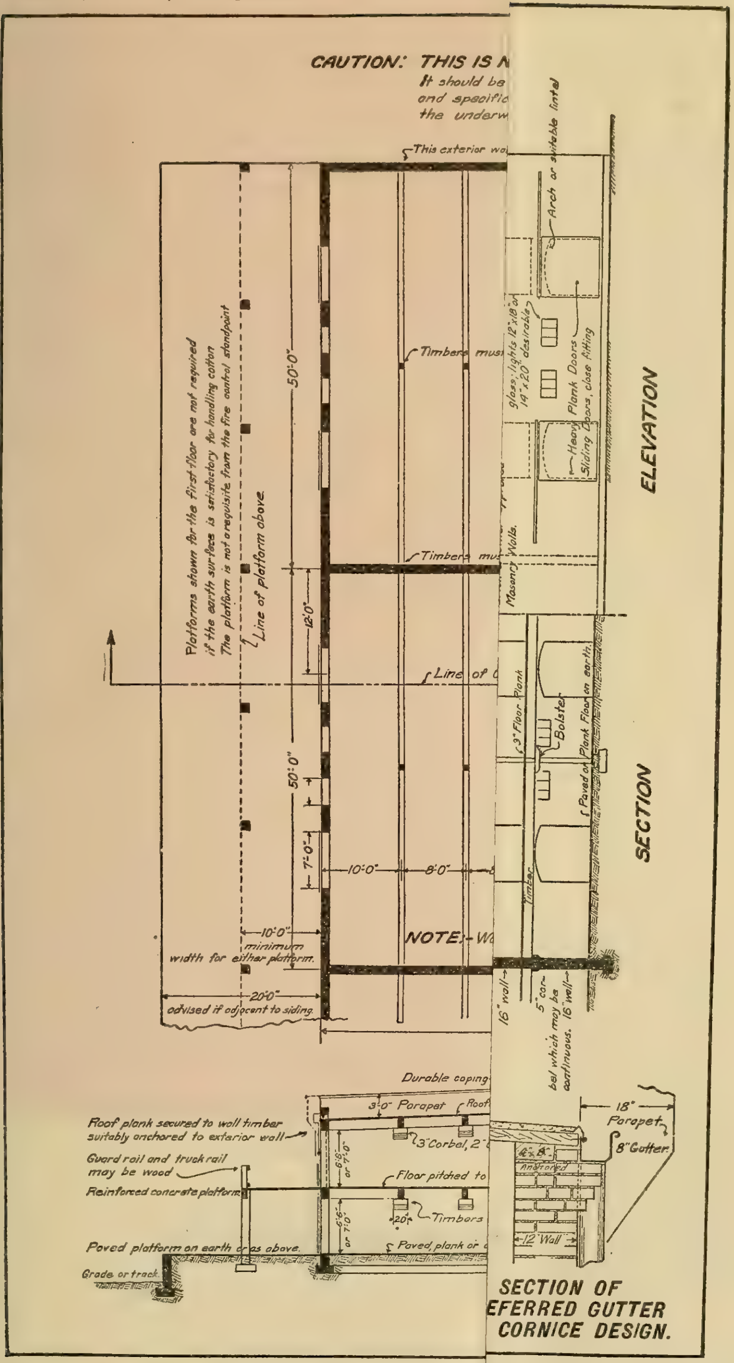
SEMISLOW-BURNING WAREHOUSE DESIGN W2A.

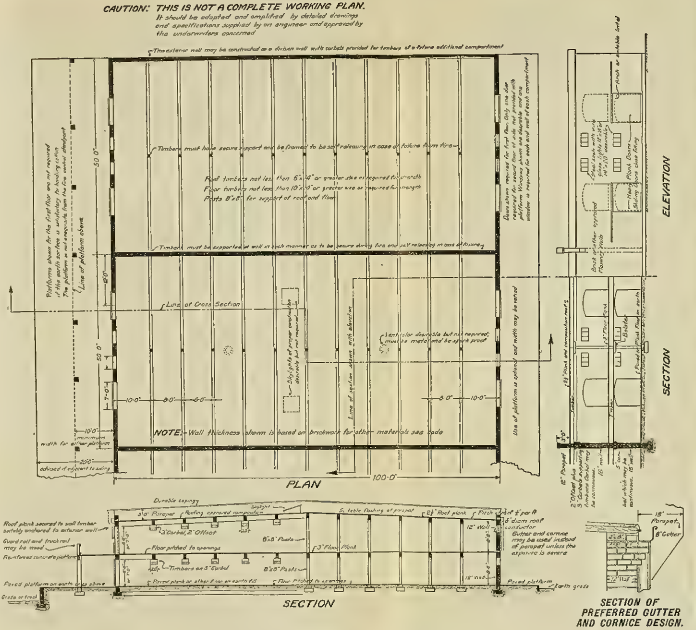

CAUTION: T
It
on
This exteri
Exterior wall 12"
or reinforced conc
5" diam roof conductor
Steel sash
5" diameter conductor
50'0"
12'0"
50'0"
7'0"
Sliding doors
10'0"
8'0"
Timbers n
Timbers
If division fire wall i
bonded to the exteri
wall must extend in
face of the exterior
Line of
Division
Platforms shown may be varied in width
They may be omitted if earth surface is
satisfactory for handling cotton
Paved or reinforced concrete
platforms
20'0"
desirable for siding.
wire glass lights
12"x18". Sash stationary
Doors fire-resistive (sliding)
or heavy planking if no exposure.
5" diam Conductor
ELEVATION
Paved or plank floor or earth
SECTION
3" Corbels supporting
timbers. Corbel
may be continuous
Wall of brick 16" or
rein. con. 12"
Durable
18" or 24" Parapet if there
is a severe exposure. If
not use gutter as shown
2½" Roof plank
Pitc
3" Corbel, 2"
red
ere
6'6"
or 7'0"
Concrete platform
Paved, plank
Grade or track
18"
Parapet
8" Gutter
12" Wall
SECTION OF
EFERRED GUTTER
CORNICE DESIGN.


CAUTION: THIS IS NOT A COMPLETE WORKING PLAN.
It should be adopted and amplified by detailed drawings and specifications.
This exterior wall may be constructed as a division fire wall with corbels provided for timbers for future addition
Exterior wall 12" thick for brick or reinforced concrete.
Timbers must have secure supports and be framed to be self releasing in case of failure
Roof timbers not less than 6"x14" or greater size as required for strength.
Posts 8"x8" for support of roof timbers.
Timbers must be supported at wall in such manner as to be secure during fire and self releasing
If division fire wall is not of same material and bonded to the exterior wall, the division fire wall must extend into and within 4" of the outer face of the exterior wall.
Line of cross section.
Skylights of wire glass in metal frame desirable but not required 4'x6' or 6'x6' desirable
Line of section
Ventilators desirable but not required. Must be metal and spark-proof
Division fire wall 16" thick for brick and 12" for reinforced concrete.
Platforms shown may be varied in width. They may be omitted if earth surface is satisfactory for handing cotton
Paved or reinforced concrete platforms
5" diam roof conductor
5" diameter conductor
Steel sash
Sliding doors
50'0"
12'0"
80'0"
7'0"
10'0"
8'0"
8'0"
8'0"
10'0"
20'0"
desirable for siding
100'0"
10'0"
Sliding doors - heavy plank or fire-resistive
Platform paved or reinforced concrete
Stationary steel sash - wire glass
5" diam roof conductor
Use of platform is optional and width may be varied
PLAN
Durable coping
18" or 24" Parapet if there is a severe exposure. If not use gutter as shown
2½" Roof plank, Pitch ¼" per ft.
Approved composition roofing
Skylight
ventilator
Suitable flashing at parapet 3'0"
3" Corbel, 2" Offset
8"x8" Posts
Windows steel sash with wire glass Stationary
Scupper
Roof conductor 5" diameter.
Gutter and cornice may be used instead of parapet if exposure is not severe
6'6" or 7'0"
Concrete platform
Paved, plank or other floor on fill
Floor pitched to openings
Concrete platform
Grade or tracks
SECTION.
18
Parapet & Gutter
4x6 Anchored
12" Wall
SECTION OF PREFERRED GUTTER AND CORNICE DESIGN.
Steel sash with wire glass lights 12"x18" Sash stationary
Doors fire-resistive (sliding) or heavy planking if no exposure
Scupper and 5" diam Conductor
ELEVATION
Ventilator-spark proof
Bolster
Skylight
Timbers
Paved or plank floor on earth
12" Parapet
2" Offset plus 3" Corbels supporting timbers. Corbel may be continuous
Wall of brick 16" or rein con 12"
SECTION

SLOW-BURNING WAREHOUSE DESIGN S1A.

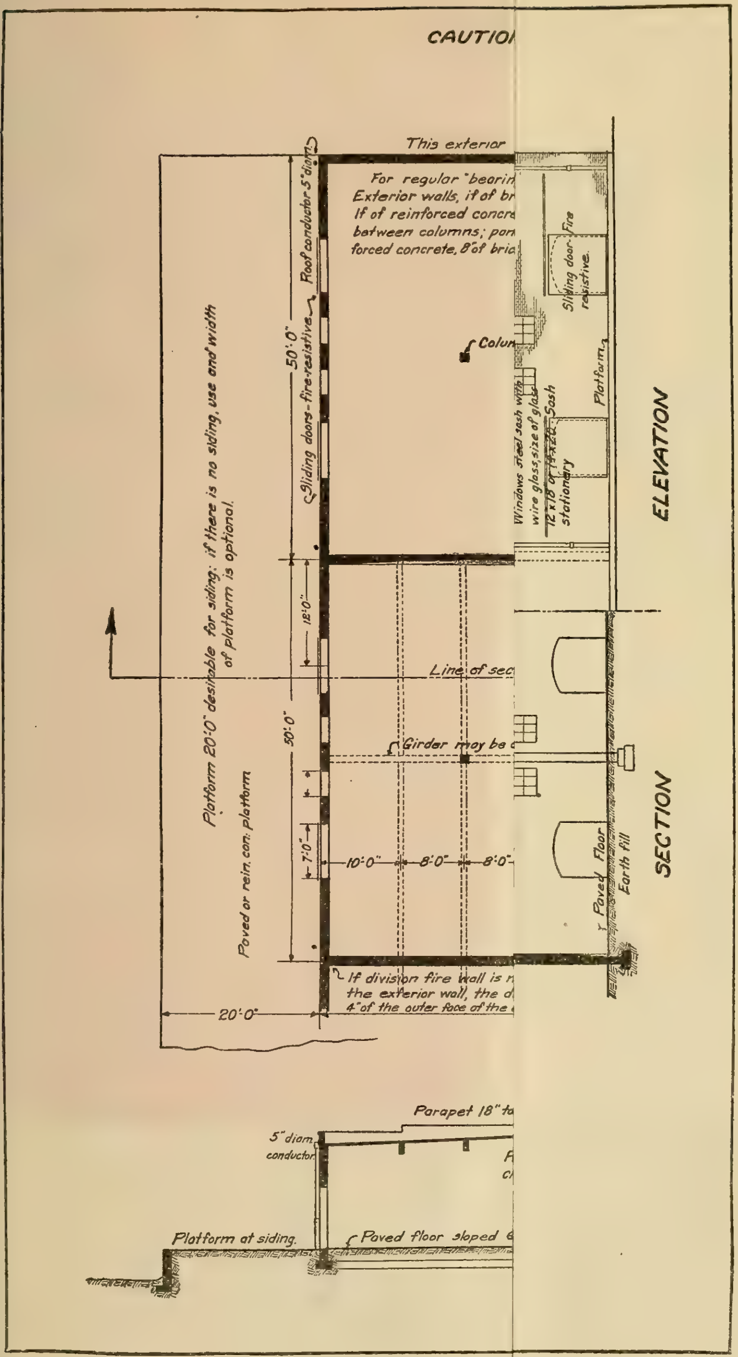
PLAN S2A.

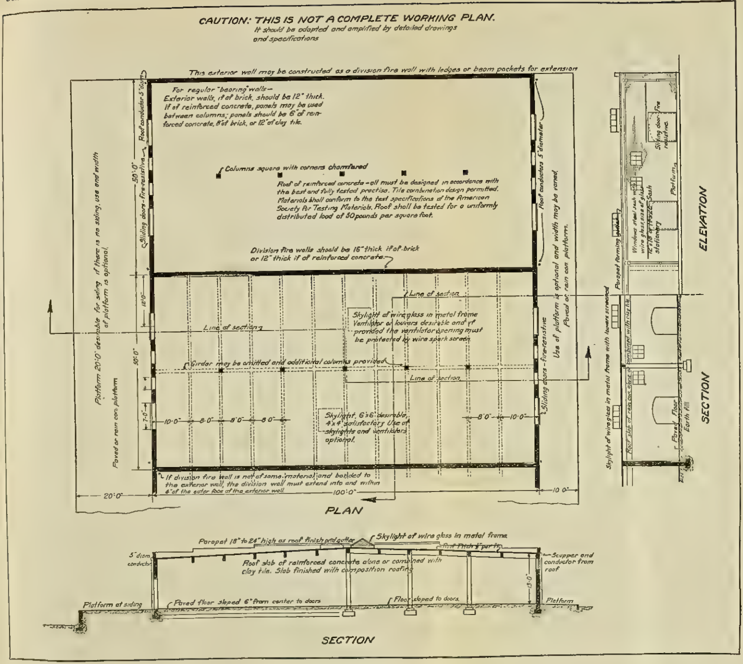

CAUTION: THIS IS N
It should be
and specific
the underw
This exterior wa
Arch or suitable lintel
glass; lights 12"x18" or 14"x20" desirable
Heavy Plank Doors
Sliding Doors, close fitting
ELEVATION
Timbers must
Timbers mu
Masonry Walls.
Platforms shown for the first floor are not required
if the earth surface is satisfactory for handling cotton
The platform is not a requisite from the fire control standpoint
Line of platform above
50'-0"
12'-0"
50'-0"
7'-0"
10'-0"
8'-0"
Line of
3" Floor Plank
Bolster
Paved or Plank Floor on earth.
Timber
SECTION
NOTE:- W
10'-0" minimum width for either platform.
20'-0" advised if adjacent to siding.
16" wall
5" corbel which may be continuous.
16" wall
Durable coping
3'-0" Parapet
Roof
Roof plank secured to wall timber suitably anchored to exterior wall
3" Corbel, 2"
Guard rail and truck rail may be wood
6'-6" or 7'-0"
Floor pitched to
Reinforced concrete platform
Timbers
20"
Paved platform on earth or as above.
Paved, plank or
Grade or track
18"
Parapet
8" Gutter
4"x8" Anchored
12" Wall
SECTION OF
EFERRED GUTTER
CORNICE DESIGN.


CAUTION: THIS IS NOT A COMPLETE WORKING PLAN.
It should be adapted and amplified by detailed drawings and specifications supplied by an engineer and approved by the underwriters concerned
This exterior wall may be constructed as a division wall with corbels provided for timbers of a future additional compartment
Timbers must have secure support and be framed to be self releasing in case of failure from fire
Roof timbers not less than 6"x14" or greater size as required for strength
Floor timbers not less than 10"x14" or greater size as required for strength
Posts 8"x8" for support of roof and floor
Timbers must be supported at wall in such manner as to be secure during fire and self releasing in case of failure
Platforms shown for the first floor are not required if the earth surface is satisfactory for hauling cotton. The platform is not adequate from the fire control standpoint
Line of platform above
50'0"
12'0"
Line of Cross Section
Skylights of proper construction desirable but not required
Line of section shown with elevation
Ventilator desirable but not required; must be metal and be spark proof
Doors shown required for first floor. Only one door required for second floor at side not provided with platform. Windows shown are desirable and one window is required for each end wall of each compartment
Use of platform is optional and width may be varied
50'0"
7'0"
10'0"
8'0"
8'0"
8'0"
10'0"
NOTE:- Wall thickness shown is based on brickwork for other materials see code
10'0" minimum width for either platform
20'0" advised if adjacent to siding
100'0"
PLAN
Arch or suitable lintel
Steel sash with wire glass, lights 12"x18" or 14"x20" desirable
Heavy Plank Doors
Sliding Doors close fitting
Brick or other approved Masonry Walls
ELEVATION
2½" Plank and composition roof
Timber
3" Floor Plank
Bolster
Paved or Plank Floor on earth
3'0"
12" Parapet
2" Offset plus 3" Corbels supporting timbers Corbel may be continuous.
16" wall
5" corbel which may be continuous. 16" wall
SECTION
Durable coping
Skylight
3'0" Parapet
Roofing approved composition
Suitable flashing at parapet
2½" Roof plank
Pitch of roof ¼" per ft
Roof plank secured to wall timber suitably anchored to exterior wall
3" Corbel, 2" Offset
8"x8" Posts
3" Floor Plank
12" Wall
5" diam roof conductor
Gutter and cornice may be used instead of parapet unless the exposure is severe
Guard rail and truck rail may be used
Floor pitched to openings
Reinforced concrete platform
Timbers on 3" Corbel
8"x8" Posts
16" Wall
Paved platform on earth or as above
Paved plank or other floor on earth fill
Floor Pitched to openings
Paved platform
Earth grade
Grade at track
SECTION
18"
Parapet
8" Gutter
2"x8"
12" Wall
SECTION OF PREFERRED GUTTER AND CORNICE DESIGN.

SLOW-BURNING WAREHOUSE DESIGN S2A.

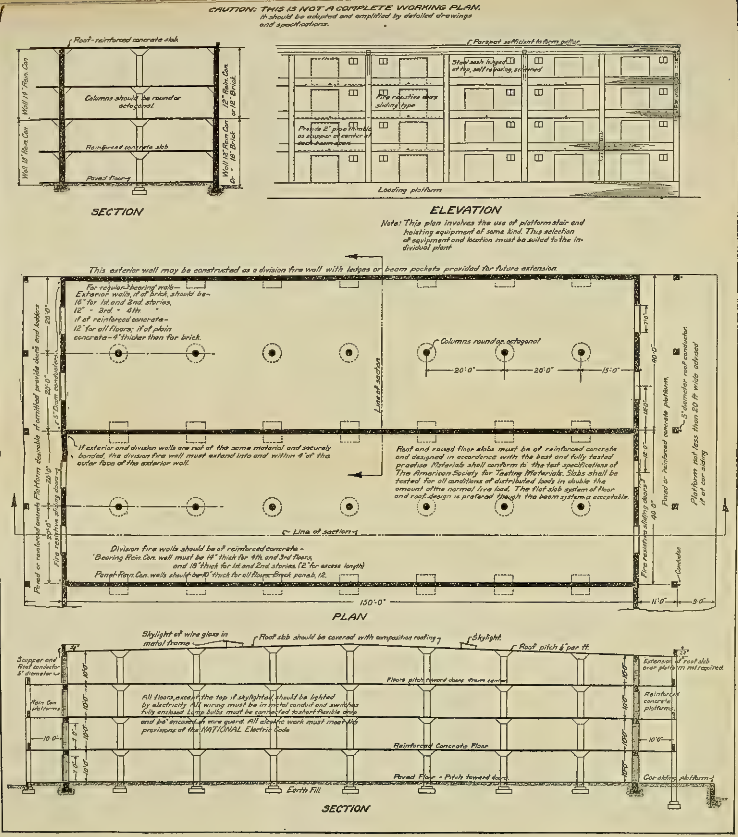
PLAN F1A.


CAUTIO
This exterior
For regular "bearin
Exterior walls, if of br
If of reinforced concre
between columns; par
forced concrete, 8" of bric
Roof conductor 5" diam.
Sliding doors - fire-resistive
50'-0"
18'-0"
50'-0"
7'-0"
10'-0"
8'-0"
8'-0"
Colum
Girder may be
Line of sec
Platform 20'-0" desirable for siding; if there is no siding, use and width of platform is optional.
Paved or rein. con. platform
20'-0"
If division fire wall is n
the exterior wall, the d
4" of the outer face of the
Sliding door - Fire resistive.
Platform
Windows steel sash with wire glass, size of glass 12"x18" or 14"x20". Sash stationary
ELEVATION
Paved Floor
Earth fill
SECTION
Parapet 18" to
5" diam. conductor
Platform at siding.
Paved floor sloped


CAUTION: THIS IS NOT A COMPLETE WORKING PLAN.
It should be adapted and amplified by detailed drawings and specifications
This exterior wall may be constructed as a division fire wall with ledges or beam pockets for extension
For regular "bearing" walls— Exterior walls, if of brick, should be 12" thick. If of reinforced concrete, panels may be used between columns; panels should be 6" of reinforced concrete, 8" of brick, or 12" of clay tile.
Columns square with corners chamfered
Roof of reinforced concrete—all must be designed in accordance with the best and fully tested practise. Tile combination design permitted. Materials shall conform to the test specifications of the American Society for Testing Materials. Roof shall be tested for a uniformly distributed load of 50 pounds per square foot.
Division fire walls should be 16" thick if of brick or 12" thick if of reinforced concrete.
Roof conductor 5" diam.
Sliding doors—fire-resistive
Roof conductors 5" diameter
Use of platform is optional and width may be varied.
Paved or rein con. platform.
Platform 20'0" desirable for siding, if there is no siding, use and width of platform is optional.
Paved or rein con. platform
50'0"
12'0"
50'0"
7'0"
Line of section
Line of section
Line of section
Skylight of wire glass in metal frame Ventilator or louvers desirable and if provided the ventilator opening must be protected by wire spark screen.
Girder may be omitted and additional columns provided
Skylight, 6'x6' desirable, 4'x4' satisfactory. Use of skylights and ventilators optional.
10'0" 8'0" 8'0" 8'0"
8'0" 10'0"
Sliding doors—fire-resistive
If division fire wall is not of same material and bonded to the exterior wall, the division wall must extend into and within 4" of the outer face of the exterior wall.
20'0"
100'0"
10'0"
PLAN
Parapet 18" to 24" high as roof finish and gutter
Skylight of wire glass in metal frame
Roof Pitch ¼" per ft.
5" diam. conductor
Roof slab of reinforced concrete alone or combined with clay tile. Slab finished with composition roofing
Scupper and conductor from roof
13'0"
Platform at siding
Paved floor sloped 6" from center to doors
Floor sloped to doors.
Platform
SECTION
Parapet forming gutter
Windows steel sash with wire glass, size of glass 12"x18" or 14"x20". Sash stationary
Sliding door. Fire resistive.
Platform
ELEVATION
Skylight of wire glass in metal frame with louvers screened
Roof slab of rein. con. alone or combined with clay tile
Paved Floor
Earth fill
SECTION

FIRE-RESISTIVE WAREHOUSE DESIGN F1A.

CAUTION: THIS IS NOT A COMPLETE WORKING PLAN



CAUTION: THIS IS NOT A COMPLETE WORKING PLAN. It should be adopted and amplified by detailed drawings and specifications.

Note: This plan involves the use of platform stair and hoisting equipment of some kind. This selection of equipment and location must be suited to the individual plant

This exterior wall may be constructed as a division fire wall with ledges or beam pockets provided for future extension.

For regular "bearing" walls— Exterior walls, if of brick, should be— 16" for 1st and 2nd stories, 12" - 3rd - 4th " if of reinforced concrete— 12" for all floors; if of plain concrete—4" thicker than for brick.

If exterior and division walls are not of the same material and securely bonded, the division fire wall must extend into and within 4" of the outer face of the exterior wall.

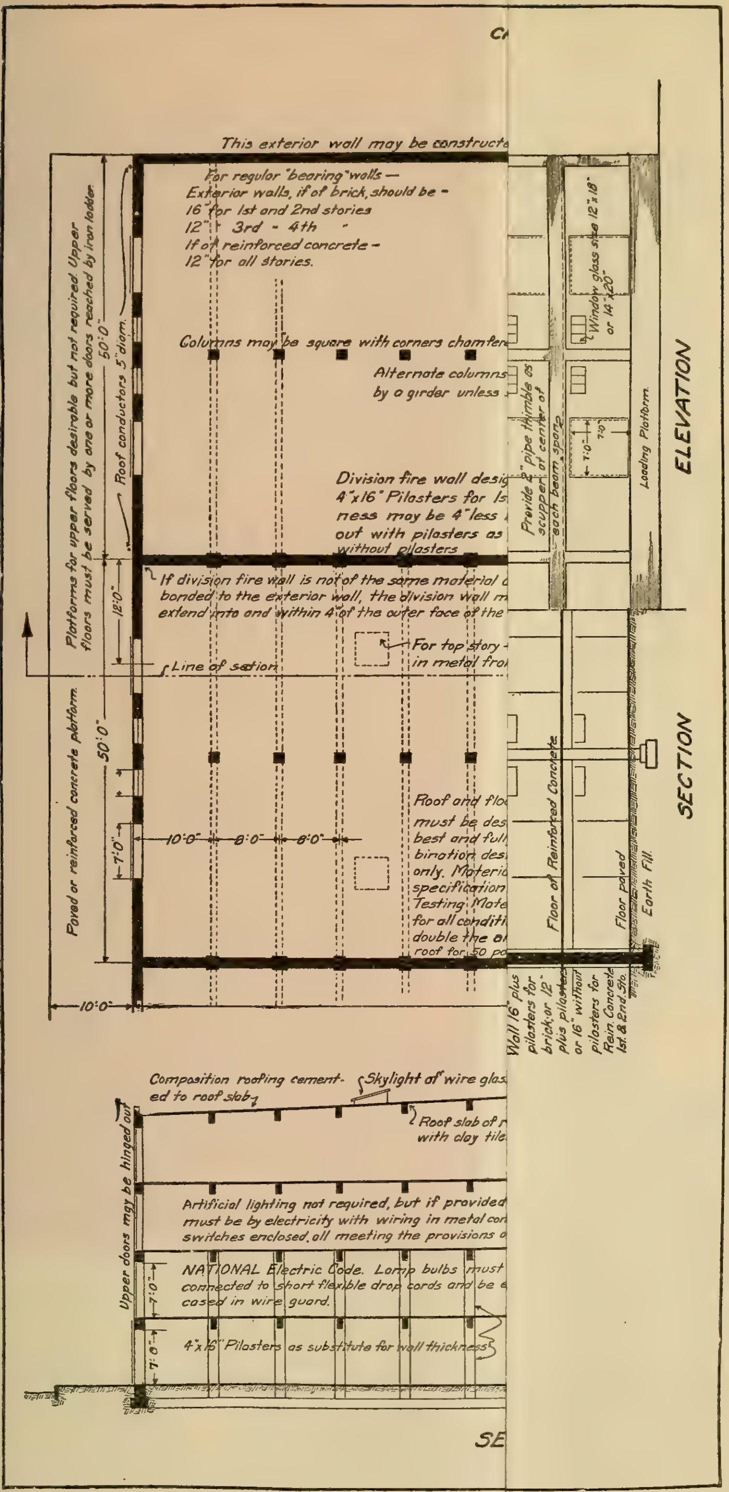
Roof and raised floor slabs must be of reinforced concrete and designed in accordance with the best and fully tested practise. Materials shall conform to the test specifications of The American Society for Testing Materials. Slabs shall be tested for all conditions of distributed loads in double the amount of the normal live load. The flat slab system of floor and roof design is prefered though the beam system is acceptable.

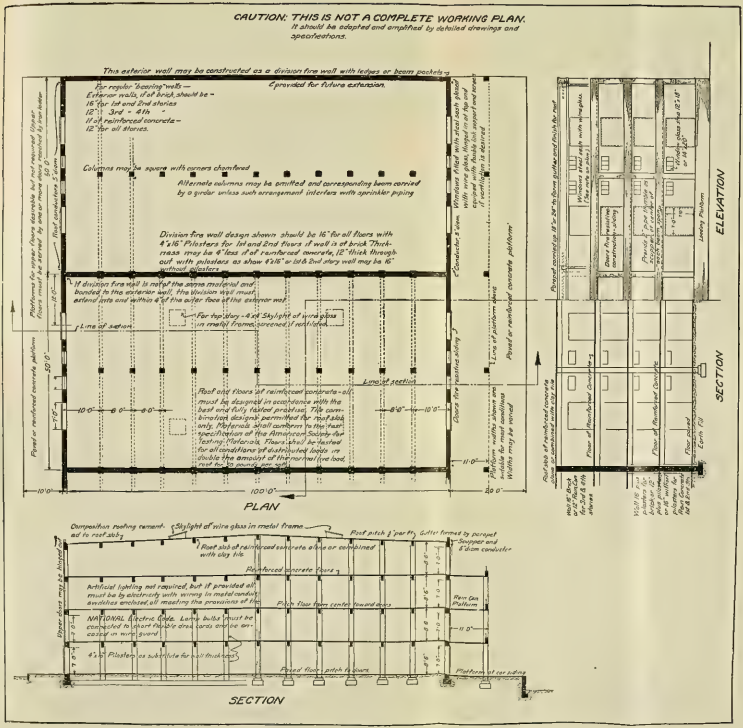
Division fire walls should be of reinforced concrete— 'Bearing Rein. Con. wall must be 14" thick for 4th and 3rd floors, and 18" thick for 1st and 2nd stories. (2" for excess length) Panel-Rein. Con. walls should be 10" thick for all floors. Brick panels, 12.

All floors, except the top if skylighted, should be lighted by electricity. All wiring must be in metal conduit and switches fully enclosed. Lamp bulbs must be connected to short flexible cord and be encased in wire guard. All electric work must meet the provisions of the NATIONAL Electric Code

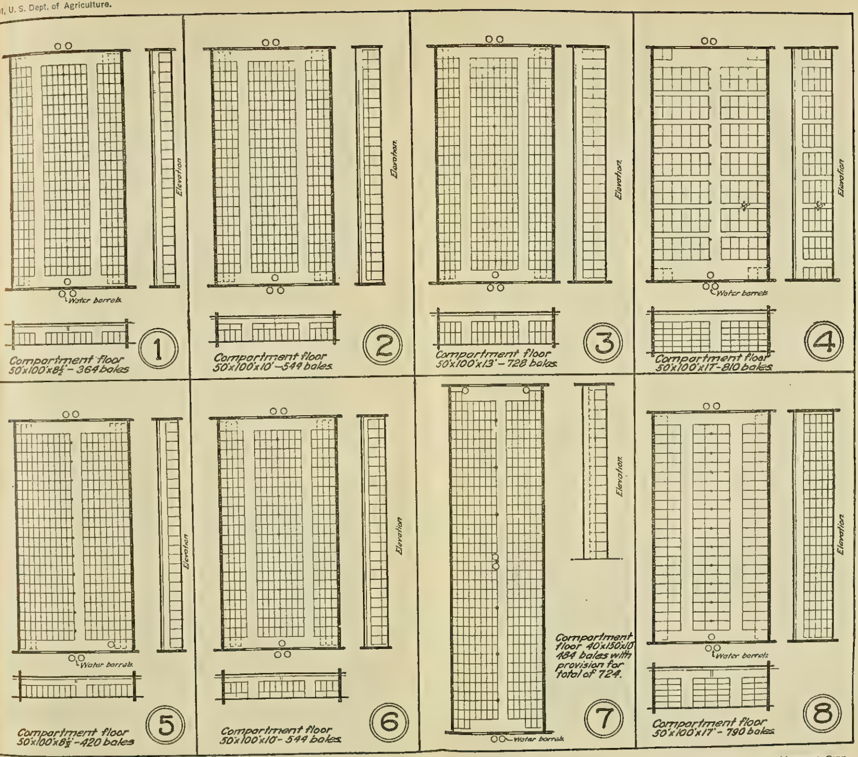
Roof-reinforced concrete slab.
Columns should be round or octagonal.
Reinforced concrete slab.
Paved floor
Wall 14" Rein. Con
Wall 18" Rein. Con
12" Rein. Con. or 12" Brick.
Wall 12" Rein. Con. Or " 16" Brick
SECTION
Parapet sufficient to form gutter
Steel sash hinged at top, self releasing, screened
Fire resistive doors sliding type
Provide 2" pipe thimble as scupper at center of each beam span
Loading platform
ELEVATION
Columns round or octagonal
20'0"
20'0"
15'0"
Line of section
Line of section
Paved or reinforced concrete Platform desirable if omitted provide doors and ladders
5" Diam conductors
Fire resistive sliding doors
20'0"
20'0"
20'0"
20'0"
7'0"
15'0"
12'0"
40'0"
40'0"
Fire resistive sliding doors
Paved or reinforced concrete platform.
5" diameter roof conductor
Platform not less than 20 ft wide advised if at car siding
Conductor
150'-0"
11'0"
9'0"
PLAN
Skylight of wire glass in metal frame
Roof slab should be covered with composition roofing
Skylight.
Roof pitch ¼" per ft.
Scupper and Roof conductor 5" diameter
Rein Con platforms
Floors pitch toward doors from center
Reinforced Concrete Floor
Paved Floor - Pitch toward doors
Earth Fill
Extension of roof slab over platform not required.
Reinforced concrete platforms.
Car siding platform
10'0"
10'0"
10'0"
10'0"
10'0"
10'0"
10'0"
10'0"
10'0"
10'0"
7'0"
7'0"
SECTION

Fire-Resistive Warehouse Design F4a.


CA
This exterior wall may be constructe
For regular "bearing" walls —
Exterior walls, if of brick, should be -
16" for 1st and 2nd stories
12" " 3rd - 4th "
If of reinforced concrete -
12" for all stories.
Columns may be square with corners chamfer
Alternate columns
by a girder unless
Division fire wall desig
4"x16" Pilasters for 1s
ness may be 4" less
out with pilasters as
without pilasters
If division fire wall is not of the same material a
bonded to the exterior wall, the division wall m
extend into and within 4" of the outer face of the
For top story
in metal fra
Line of section
Roof and flo
must be des
best and full
bination des
only. Materia
specification
Testing Mate
for all conditi
double the a
roof for 50 po
10'0"
8'0"
8'0"
7'0"
18'0"
50'0"
50'0"
10'0"
Platforms for upper floors desirable but not required. Upper floors must be served by one or more doors reached by iron ladder.
Roof conductors 5" diam.
Paved or reinforced concrete platform.
Provide 2" pipe thimble as scupper at center of each beam span
Window glass size 12"x18" or 14"x20"
7'0"
Loading Platform.
ELEVATION
SECTION
Floor of Reinforced Concrete
Floor paved
Earth Fill.
Wall 16" plus pilasters for brick; or 12" plus pilasters or 16" without pilasters for Rein. Concrete 1st & 2nd Sto.
Composition roofing cemented to roof slab
Skylight of wire glas
Roof slab of r
with clay tile
Upper doors may be hinged out
Artificial lighting not required, but if provided
must be by electricity with wiring in metal con
switches enclosed, all meeting the provisions o
NATIONAL Electric Code. Lamp bulbs must
connected to short flexible drop cords and be e
cased in wire guard.
4"x16" Pilasters as substitute for wall thickness
7'0"
7'0"
SE


CAUTION: THIS IS NOT A COMPLETE WORKING PLAN.
It should be adapted and amplified by detailed drawings and specifications.
This exterior wall may be constructed as a division fire wall with ledges or beam pockets provided for future extension.
For regular bearing walls —
Exterior walls, if of brick, should be —
16" for 1st and 2nd stories
12" " 3rd " 4th "
If of reinforced concrete —
12" for all stories.
Columns may be square with corners chamfered
Alternate columns may be omitted and corresponding beam carried by a girder unless such arrangement interfers with sprinkler piping
Division fire wall design shown should be 16" for all floors with 4"x16" Pilasters for 1st and 2nd floors if wall is of brick. Thickness may be 4" less if of reinforced concrete, 12" thick throughout with pilasters as show 4"x16" or 1st & 2nd story wall may be 16" without pilasters
If division fire wall is not of the same material and bonded to the exterior wall, the division wall must extend into and within 4" of the outer face of the exterior wall.
For top story - 4'x4' Skylight of wire glass in metal frame, screened if ventilated.
Line of section
Line of section
Roof and floors of reinforced concrete - all must be designed in accordance with the best and fully tested practise. Tile combination designs permitted for roof slab only. Materials shall conform to the test specification of the American Society for Testing Materials. Floors shall be tested for all conditions of distributed loads in double the amount of the normal live load, roof for 50 pounds per sq. ft.
Platforms for upper floors desirable but not required. Upper floors must be served by one or more doors reached by iron ladder
Roof conductors 5" diam.
50' 0"
12' 0"
50' 0"
7' 0"
10' 0"
8' 0"
8' 0"
8' 0"
10' 0"
11' 0"
10' 0"
100' 0"
20' 0"
Paved or reinforced concrete platform
Windows fitted with steel sash glazed with wire glass, hinged in at top and equiped with fusible link support and screen if ventilation is desired
Conductor, 5" diam.
Doors fire resistive sliding
Line of platform above
Paved or reinforced concrete platform
Platform widths shown are suitable for most conditions. Widths may be varied
PLAN
Parapet carried up 18" or 24" to form gutter and finish for roof
Windows steel sash with wire glass. (See note on plan.)
Doors fire resistive construction - sliding
Provide 2" pipe thimble as scupper at center of each beam span
Window glass size 12"x18" or 14"x20"
7' 0"
7' 0"
Loading Platform
ELEVATION
Roof slab of reinforced concrete alone or combined with clay tile
Floor of Reinforced Concrete
Floor of Reinforced Concrete
Floor paved
Earth Fill
Wall 16" Brick or 12" Rein. Con. for 3rd & 4th stories
Wall 16" plus pilasters for brick or 12" plus pilasters or 16" without pilasters for Rein. Concrete 1st & 2nd sty.
SECTION
Composition roofing cemented to roof slab
Skylight of wire glass in metal frame.
Roof pitch ¼" per ft.
Gutter formed by parapet
Scupper and 5" diam conductor
Roof slab of reinforced concrete alone or combined with clay tile
Reinforced concrete floors
Upper doors may be hinged out
Artificial lighting not required, but if provided all must be by electricity with wiring in metal conduit, switches enclosed, all meeting the provisions of the NATIONAL Electric Code. Lamp bulbs must be connected to short flexible drop cords and be encased in wire guard
Pitch floor from center toward doors
Rein. Con. Platform
4"x16" Pilasters as substitute for wall thickness
Paved floor - pitch to doors
Platform at car siding
8' 0"
8' 6"
8' 0"
8' 6"
7' 0"
7' 0"
7' 0"
7' 0"
7' 0"
7' 0"
11' 0"
SECTION

FIRE-RESISTIVE WAREHOUSE DESIGN F4B.



1 Compartment floor 50'x100'x8½' – 364 bales

2 Compartment floor 50'x100'x10' –549 bales

3 Compartment floor 50'x100'x13' – 728 bales

4 Compartment floor 50'x100'x17-810 bales

5 Compartment floor 50'x100'x8½'-420 bales

6 Compartment floor 50'x100'x10'- 544 bales

7 Compartment floor 40'x150'x10 484 bales with provision for total of 724.

8 Compartment floor 50'x100'x17' - 790 bales

DIAGRAM SHOWING SKETCHES OF VARIOUS ARRANGEMENTS FOR STORING COTTON SHOWING THE NUMBER OF BALES WHICH MAY BE ARRANGED IN COMPARTMENTS OF VARIOUS SIZE.

UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 802
Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.   PROFESSIONAL PAPER   December 29, 1919

QUALITY AND VALUE OF IMPORTANT TYPES OF PEAT MATERIAL.

A CLASSIFICATION OF PEAT BASED UPON ITS BOTANICAL COMPOSITION AND PHYSICAL AND CHEMICAL CHARACTERISTICS.

By Alfred P. Dachnowski,
Physiologist, Soil-Fertility Investigations.

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THE PRESENT STATUS OF PEAT UTILIZATION.

The problem of peat utilization may be analyzed from several points of view, but only a few aspects of the subject are of essential importance to emphasize at this time. Among the peat problems in question none, in the opinion of the writer, is so serious as the failure to realize the existence of the important grades or types of this material in regard to quality and their relative value for agriculture or other uses.

There is a growing recognition of the fact that the term "peat" is too general to be applied to plant remains essentially different in composition, which have different agricultural and technical possibilities, and which vary greatly according to regional distribution and topographic features, even in the same deposit. Not only a proper understanding by the layman appears to be wanting, but the necessary scientific foundation is still lacking in this country which would deal with the differences in botanical composition of the various peat materials and their corresponding physical, chemical, and other characteristics of practical importance to the farmer, the technician, the manufacturer, and the scientist as well. A recognition of these differences, it is believed, would emphasize to those using peat land the inherent possibilities and limitations of the organic materials. From the standpoint of the State agencies and local investigators this is a specific problem of an urgent character underlying the sound and rational use of such land. Neither the selection of peat deposits of practical value for certain crops or for specific technical purposes nor the close correlation which exists between the botanical composition of the different peat materials and its corresponding physical, chemical, cultural, economic, or other merits can be attempted successfully until consideration is given to the important types of this material found in this country.

It is precisely this information which would enable one to form a correct judgment concerning the structural profile of peat deposits which accumulate under the widely differing climatic, topographic, geologic, and vegetational conditions of this country; and it is this aspect of the problem that would supply the essential criteria concerning the manner of developing a peat area for specific agricultural or technical purposes, or for a combination of agriculture with a varied manufacturing utilization, where under the pressure of strenuous circumstances this development must needs be centralized near a source of supply of raw material to insure financial success.

If we attempt to formulate the status of peat investigations in the United States and compare it with that of Holland, Sweden, Austria, or Germany; if we appraise in these countries and our own the degree of success in utilizing the various types of this material directly applicable to certain forms of agriculture or to economic industries; or if we compare the respective results of scientific investigations and the literature on the subject, based upon well-established, definitely described classes of deposits or groups of peat material, we shall have to acknowledge that we are far behind the position we ought now to occupy by right of resources and opportunities. The lack of information on which a wise decision should be based and the absence of any prospect of continuous or satisfactory returns have led in many places to a lack of confidence and to the abandonment of attempts to bring peat-land areas to a profit-yielding basis.

On the continent of Europe much effort is now devoted to encouraging the development of distinct classes of peat land. Good and relatively poor peat areas are reclaimed at much less cost than was formerly the experience. It is principally through the detailed collation of information for many years past, regarding the formation, structure, and distribution of different kinds of peat deposits, and the botanical, physical, and chemical differences of the various types of their organic contents, as well as through the systematically conducted observations of the several field conditions to be considered, that a corresponding profitable and varied development in the use of these resources has been possible.

More and more in this country the demand is becoming urgent for information concerning peat materials which affect the productiveness and health of crops. Information is called for in estimating the value, the supply, and the possible range of usefulness of special grades of peat for specific crops or for manufactures, for that yielding a satisfactory material as a carrier for bacterial organisms, for fertilizer purposes, for litter, fuel, or distillation products, and for other uses. Advice is needed to point out the difficulties to be avoided, especially when an area of peat land may be developed for both agricultural and technical purposes by communities or associations and may be made increasingly profitable because of the equal, if not greater, value of the underlying mineral soil for staple crops, for special forms of economic plants, or for intensified methods of farming.

There are many instances of failure of efforts based on impractical and previously discarded ideas which time and again have been tried on an extensive scale in Europe and in this country, only to meet the same experience. The traditional disregard for facts of a qualifying nature, or for drawing a plan having due regard for the existing factors and needs of an undertaking; the inability of scientific workers to understand or to compare critically each other's researches in the field of peat investigations, because the terms peat and muck are not qualified and because faulty conceptions regarding them have still an unchallenged place in the scientific literature of this country—these are some of the results of the present situation, and for both national and economic reasons they reflect indeed a serious condition.

Types of peat material, their differences in botanical composition, in disintegration capacity, and in related physical and chemical characteristics have been established in Europe by many years of experience and scientific investigation. They form an adequate basis in problems which deal with methods to be practiced in the development and cultural preparation of a peat deposit, such as the well-known "Veenkultur," the Rimpau cultural method, the German high-moor method, and others, or in operations where the removal of peat for technical uses and centralized power plants is practicable. Data such as those just mentioned, regarding the nature and behavior of the various types of disintegrating plant remains making up a peat deposit, are considered of special importance in drainage projects intended to be practicable from an engineering and agricultural standpoint; they are essential for an adequate method of dewatering peat materials that are found to be of value for manufacturing purposes. It is rather in the knowledge of the different kinds of peat material, the factors in the field which brought about their accumulation and determined their character, that a satisfactory basis has been found for the improvement of peat by means of suitable crops or by specific operations in the technical industries.

Few phases of botanical inquiry have received as much attention as the development and formation of peat deposits; yet information concerning them appears to be little known and still less considered in practice, though the classical investigations of Andersson (1),[1] Clements (4), Graebner (12), Lesquereux (16), Lorenz (17), Potonié (19), Sendtner (21), Sitenský (22), and especially the works of Früh and Schröter (10), Grisebach (13), Steenstrup (4), Vaupell (23), and Weber (25) are not only comprehensive but fundamental in problems relating to the structure and content of peat deposits.

The attempt to establish a correlation between vegetation and any one factor of the environment is difficult, and though not all field work is of a nature adapted to throw light on this vexed question it has, nevertheless, been possible to make such a correlation in the lines of physical and chemical studies with types of peat material distinct in botanical composition and in degree of disintegration. Practically all the work is thus far European, and the leading investigations, notably those of Bersch (2), Birk (3), Feilitzin (9), Gully (14), Hoering (15), Minssen (18), Virchow (24), and Zailer and Wilk (26–27), follow for the most part modern botanical viewpoints and definitions.

The botanical, physical, and chemical nature of the different peat materials is of the widest practical importance, since it is in general more difficult to change the nature of the vegetable mass than to remedy its deficiencies, but almost equally important is the character of the mineral soil underlying the plant remains. The geological relations have their most important significance in the fact that decaying organic matter and carbonated water have a relatively high solvent action on the minerals of soils and rocks. This effect increases with the area covered by the accumulating masses of peat materials and especially with thicknesses in which oxidizing conditions are absent. Underlying and marginal soils derived from sedimentary, metamorphic, and eruptive rocks, both basic and acid, correspondingly affect the content and quality of peat materials in saline impurities and in acid, alkaline, or neutral reaction. Some of these rock formations yield marked amounts of soluble injurious salts.

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[1] The serial numbers in parentheses refer to "Literature cited" at the end of this bulletin.

Special climatic conditions influence appreciably the disintegration of peat materials, the formation of organic colloidal débris, and the direction of movement or transport of dissolved mineral constituents (8). The reactions may lower the supply and concentration of nearly all available essential plant-food constituents and thus effect malnutrition, a prevalence of plant diseases, and allow certain plants and microorganisms to outgrow others, or they may lead to local accumulations of salts at the surface of the peat deposit or at the margins and in the mineral substratum underneath peat accumulations. Cultural practices and drainage systems in no small measure may favor and accentuate both the contamination through the movement of underground waters or springs in peat materials with high decay capacity and the concentration of salts by seepage or by evaporation. More consequential still are the effects of a pronounced inland or a typical oceanic climate on the disintegration, absorption, deposition, and leaching phenomena. Aside from the presence of either an abundance or a deficiency of agriculturally desirable mineral constituents, the climatic contrasts give rise to classes of peat land which resemble closely the "Tschernosem" and the "Podsol" condition featured by foreign writers (11).

It is obvious, therefore, that those inquiries are likely to be most fruitful which are concentrated first of all on the fundamental problem of determining and characterizing the types of peat material which are representative of distinct regional divisions or geographic areas of the United States and reserve for later discussion the details of the structure and contents of special peat deposits which are considered to be either with or without great value or are selected as representative peat deposits for specific experimental or industrial purposes.

It seems to the writer eminently desirable at this time to give consideration especially to those chief types of peat material in this country which are characteristic of peat deposits in European countries; to emphasize mainly the grades or types which resemble or coincide with each other and whose botanical composition is based upon the remains of plants known to occur in Europe; and to characterize those phases which are preserved conspicuously in a similar stage of disintegration in this country, irrespective of their positional relationship in the different layers of a peat deposit. They alone demand consideration in the present state of our imperfect knowledge, partly because through the recognition of these types considerable progress can be made in the fixing of standards of quality and in securing their adoption; largely, however, because the physical and chemical characteristics of these types have been systematically worked out by European scientists and their investigations contain a number of important contributions which are of value for several lines of work in peat utilization.

In this country the character of several of the peat materials of both fresh-water and salt-water origin differs in various respects from that of the European Continent. This difference would probably necessitate a special grouping and series of standards. Under the varying conditions of environment existing over the great regions of the United States in which peat materials may be found, the resulting types and their relative values must, obviously, vary quite as much on account of the distribution of peat-forming vegetation and the effects of the regional geological conditions and climate as on account of the local topography or the nature and position of the ground water in and upon which the plant remains are accumulating. So far, however, as the characterization is based upon differences of botanical composition rather than the stratigraphic series or upon differences in the vegetational surface cover or regional or local modifying field influences, the lines of demarcation are simple and sharp. The general recognition of the botanical composition of peat materials would initiate a movement in the direction of effective use of specific peat-land areas, and it might bring about a more satisfactory coordination of scientific activities. There is little doubt that on some such basis as this a closer union of the several lines of research and farm practices would be mutually beneficial and scientifically as well as agriculturally and economically profitable.

How much there is need for information of this kind may well be illustrated by consideration of the following facts. In many instances projects of drainage and reclamation which appeared feasible from an engineering standpoint have proved unprofitable as an agricultural investment, mainly through the scant consideration of adequate agricultural criteria which would render the work advisable or the project economically sound. In most cases the result proved unsatisfactory through lack of information concerning the merits and adaptability of the peat materials and the nature of the field conditions limiting their possibilities. It is easily ascertained whether a deposit may be drained to the bottom or only through the deepening of the outlet channel or by diking and pumping. But the nature of the plant remains, their disintegration capacity and resistance to weathering, the amount of shrinkage to be anticipated, the influence upon them of marginal mineral soils, springs, and ground waters, the features which might impair the value of the mineral subsoil for future agricultural uses—these are not so readily determined. Too much care can not be taken in the preliminary examination of peat land before proposing improvements. Through advisory measures it is possible to forestall mistaken effort, to weed out undesirable enterprises, to select such deposits as can profitably be left as permanent "water-storing" reservoirs, preserved in their natural condition, and to assist individual or cooperative attempts in maintaining in an efficient manner those projects which are approved by agricultural merit, by economic need, by favorable markets and transportation facilities, or by the promotion of public health.

On many of the peat deposits which are peculiar in their type of material, in acidity, or in salt content, imitation of practice has led to their use for crops grown in succession at the expense of other agricultural industries, such as tillage farming combined with pasture, live-stock, or dairy farming, which would have been more suitable and would more regularly produce profitable returns. It is to be regretted that practically no extensive use has been made of the grasses, cereals, and fruit trees which are suitable for peat-land types and could be profitably developed. The natural extension of crops possible on peat areas is deserving of more systematic attempts, because it will be necessary to devote unusual attention in the near future to protect reclaimed deposits of peat now under cultivation against preventable difficulties. The more advanced agriculture becomes, the more diversified are its crop activities and the less will be the risk which attends concentration in a single field of cropping activity. Any work with the view of determining what methods of diversified agriculture are best adapted to and would benefit a certain locality or region, whether carried on by private individuals, communities, scientific institutions, or manufacturing interests, would prevent a great deal of loss to the owners of peat land and others uninformed of the limitations of different classes of peat deposits and their materials.

With the greater interest in live-stock production, the value of many abandoned peat areas as potential beef or cattle producing lands will probably again become enhanced, and it will be necessary to devote more attention than has been given to mixtures of grasses best suited to the several types of peat material or to their drainage capacity. The fact is not to be obscured that the war-time readjustments, aside from labor problems and the demands upon transportation, will tend to increase rather than lessen the need to convert forage and other crops into higher priced finished products.

Another urgent necessity is the extension of desirable peat-land areas for staple crops, notably certain cereals, if the land is annually to turn in its share and render its adequate service to the country and to the farmer. Special varieties of cereals, such as oats, rye, barley, and even wheat, are grown with success on northern European peat lands; their adoption in this country would contribute greatly not only to increased production, but also to the larger range of crop plants which is so essential to a sound and secure foundation of peat-land agriculture.

In European countries the cultivation of the better grade of cereals is carried on upon peat deposits covered with a layer of sand (the "Cunrau" or "Rimpau" method, in vogue since 1862) and upon peat areas from which most of the organic material has been removed. The practicability of combining the agricultural and commercial utilization of a peat deposit for the production of fuel and food is no longer a questionable procedure. The problem has been well solved in Holland, where certain types of material are removed partly on account of their value for manufacturing purposes; largely, however, because the mineral subsoil has an equally, if not greater, value for the production of garden truck and for staple crops. Of the two methods of developing peat land the practice of sanding peat deposits has not always proved satisfactory. European experience seems to show that the amount of injury from diseases is very small compared with losses in yield from causes due to the selection of peat areas which contained plant remains with an unfavorable decay capacity or in which there appeared in the sand cover, as time went on, relatively injurious compounds from the underlying poorly aerated organic and mineral subsoils. It is, indeed, not unlikely that similar conditions are the cause of the greatly lessened yield in the cranberry crop and other plant industries reported from some deposits in this country.

For reasons such as these, the writer feels justified in the opinion that a preliminary-survey method based upon qualitative as well as quantitative differences of peat materials, which determines their serial position in the profile structure of a deposit and their depth relation and condition of disintegration and which examines the character of the underlying mineral substratum and the nature of its ground water, would offer data which might be of general interest to various lines of peat utilization and would permit an estimate of the probable difficulties or tendencies making for failure. It would prove a more reliable means of arriving at the practical value of peat lands for an undertaking that faces agricultural or industrial utilization, or a combination of both, and it would avoid the discrediting of interests which desire to utilize peat materials for technical and commercial purposes, for bacterial inoculation, as a filler with other fertilizer substances, as a stock-feed ingredient, as fiber, and in other specific ways. It has been the experience in Europe, and undoubtedly in this country as well, that, no matter how excellent the results for a time, certain field conditions qualify the manner and methods of utilization, while the use of some types of peat material introduces sources of failure. Prudence is the more necessary in the present instance because the characterization of any native local or regional types of peat material has not as yet been coupled with definite or even preliminary botanical, physical, bacteriological, or chemical studies. This is, indeed, a cause for regret, as it is felt that a more comprehensive understanding of important types of this material, if made accessible to workers in different lines of peat utilization, might bring about a more complete coordination of their activities. Mere imitation and undue duplication of effort would be removed through an intelligent conception by each of the connection between the character of the peat deposits, their diverse materials, their value, and the uses most likely to prove successful.

DEFINITIONS AND POINTS OF VIEW IN CLASSIFYING PEAT MATERIALS.

In an endeavor to classify in some degree the results obtained in the field, a complete understanding is possible only by the consideration of various viewpoints and the meaning of the terms used. Naturally, when attempting a characterization and the grouping into classes of peat deposits and types of their material, it is desirable first to formulate clearly the fundamental lines of work along which this problem may be approached.

This consideration is important, since any controlling condition, whether relating to peat-forming vegetation units and their present distribution, to the character of initial stages of a vegetation series and the corresponding mode of accumulation of peat materials, or to the degree of disintegration and contamination of plant remains, very often compels the formation of a tentative basis upon which systematic observations may be secured. The nature of the results will depend, therefore, much on the question whether the variant plant material or the modifying, controlling, and differentiating factor of field conditions is to serve as the basis for a full characterization. Should the emphasis be placed upon the product or upon the formative process? Would the water table which controls the accumulation of peat and thus gives rise, among other distinctions, to water-formed and land-formed types of material or would differences due to the botanical composition and the sequence of vegetation units forming peat give a more satisfactory working method? Are the quality and value of materials to be determined from the vertical series or profile structure of peat deposits or from climatic and geologic features?

Two clearly related but analytically separable propositions seem to stand out as the essential premises of future work in this field of investigation. The order in which these propositions are stated is immaterial; one is as important as the other, for each is correlated with the other. Any attempt toward clarity of terms and statements, any definite determination of criteria for the classification or selection of peat deposits and their materials for agricultural or manufacturing purposes depends upon and includes a twofold qualification: (1) The botanical composition and stage of disintegration of the peat materials in a deposit and (2) the controlling basic factors in field conditions. These constitute an effectual limitation to the degree of success obtainable. The numerous abortive attempts at utilization have invariably followed from neglect of one or the other of these essential qualifying factors. Upon the recognition of these depends whether the farmer and the technician are to work by chance or on scientific lines.

It is not within the scope of this paper to deal with an ecological account of peat-forming vegetation units, of the character of initial stages, or of series of developmental stages arising in an area of a particular region. These have been discussed elsewhere in considerable detail (4; 5, p. 220-262).

The object of these notes is to call attention to the following terms and definitions:

Peat is an accumulation of plant remains in various stages of disintegration or maceration, laid down in a definite manner according to imposed modifying field conditions. For statistical purposes and for reasons of common scientific interest the use of the term "peat deposit" should be limited to an accumulation of plant remains of at least 8 to 10 inches (20 to 25 centimeters) in thickness when compact and well shrunk. In this accumulation the surface layer of living native vegetation or deposits containing more than 40 per cent of mineral matter must not be included.

Muck is a phase of surface peat material which occurs under topographic conditions permitting extensive weathering and the accumulation of large amounts of silt and clay.

Humus.—No definition can be given at present, since the well-known defects in the usual methods of humus determination have made it clear that the use of the term in its present meaning is not advisable either in statements relating to soils or fertilizers.

Marsh (fen), bog, heath, and swamp are terms used largely on account of the well-marked physiognomy of vegetation which they represent and because they are common names in many languages. The plant remains of each group accumulating as peat are among the most distinctive of peat materials, and the field conditions of each have a more or less differentiating character. The deposits are quite variable in origin and structure, but their structure is primarily dependent on the form of the land surface on which they are found and upon the height of the water table while they are formed. They are dealt with later.

The words "marsh" and "swamp," on the one hand, and "bog" and "heath," on the other, correspond in a very general way with the terms "Flachmoor" and "Hochmoor" used by most European writers. The line of distinction and the transition between them is, of course, nothing like as sharp as the terms would seem to indicate except in regions having climatic conditions where they reach their best development. "Hochmoor" is applied, as a rule, to a class of peat land which rises from the edges toward the middle and thus shows a convex upper surface. "Hochmoor," or "raised bog," develops typically in regions of high humidity or rainfall, partly on account of the habit of growth of the sphagnum mosses, which form the main component of the surface vegetation cover. "Flachmoor" represents a class of peat land with a flat or even a slightly concave surface. Often a distinction is made on the basis of chemical differences, especially the absence or presence of lime or of acid reaction, but this distinction is not exact.

Acidity may arise in various ways and it may persist only for short periods of time. A temporary condition of acidity is common to surface peat materials with insufficient aeration, weathering, or disintegration, due to the presence of carbon dioxid. It should be stated, however, that different peat materials may have different acidities, and much of the soil acidity may be potential rather than active. In bog types of peat, for example, acidity appears to be due partly to the absorbing capacity of the organic materials for bases, breaking up salts and liberating acids (14), and partly to the presence of end products of disintegration which are colloidal substances of an acid character. The activity of microorganisms and certain forms of fungi as acid builders in peat soils and the degree of activity and probable harmfulness have barely been touched by investigators (5). In the marsh types of peat, acidity is caused more frequently by the oxidation of sulphids in the underlying mineral soils or by drainage waters which have become acid through a variety of causes. In a few cases acidity is due to the long-continued application of artificial fertilizers, such as ammonium sulphate and others, that have been used on the soils too heavily. Although the cause of soil acidity and its direct or indirect effects on plants and on the physical, chemical, and biological conditions and processes of soils have been the subject of numerous investigations, any broad statement is unsafe at this time.

From the standpoint of the conditions of accumulation it is desirable to distinguish between transported peat materials, i. e., the group of peat types which were formed in open water and below the water level (the aquatic or allochthonous types of peat), and those which resulted from the preservation of plant remains on the spot actually occupied by the peat-forming vegetation units, the groups of peat material formed at and above the water level (the marsh, swamp, and bog, or autochthonous types of peat).

The group division represents the members of a linear genetic sequence or vegetation series which have the same general range of controlling field conditions, e. g., the positions of the ground-water level in relation to the surface. Regional divisions have not been taken into account at present, since they represent the broader relations of types of peat material and the marked differences which are associated with the geographic distribution of vegetation forming peat, with climate, geology, and physiographic relations.

A type of peat material is the individual member of a group and is based upon differences in origin, texture, color, etc., and in botanical composition of such plant remains as characterize the organic material most conspicuously.

Phases are differences in a type of peat not sufficiently well marked to justify a new subdivision; they are variations in composition of plant remains, in mineral matter, etc., and are in some respects correlative features of certain field conditions.

From the standpoint of the vegetation units forming peat, the layers of plant remains preserved more or less intact are much the more important. They furnish a record of the development and structure of peat deposits, and they represent a more or less definite series of different vegetation stages, each initiated, continuing, or terminated and replaced in response to changes of basic past and present modifying factors or field conditions. They indicate that of the many plants which occupied the area as an association, only the few forms or species that were dominant and of rather wide geographic distribution contributed to the formation of peat layers.

The course of the development of a peat deposit may have been complete or interrupted, complicated or recurring, according to the conditions which prevailed; the resulting layers of peat material are certain to be correspondingly continuous or fragmentary and isolated. Wherever peat deposits arise, whether in the conversion of wet flatland surfaces or of basins and kettle holes, on uplands, along river channels, or at the coast, the essential nature of the process is readily established by a comparison of the serial and contemporaneous strata of a deposit. The record is indicated by the profile structure and can be ascertained and reconstructed only by actually probing the layers of plant remains and examining microscopically the more disintegrated materials.

The stratification of a deposit points therefore to changed life relations for the plants which formed peat; to disturbances which ensued through altered conditions of rainfall, of soil moisture and its content of mineral salts, or in the relation of precipitation to evaporation. Unfavorable topographic or soil conditions may even arrest the succession of vegetation and keep it stationary at a point far short of the possible development within the area, but significant is the fact that with further accumulation of plant remains the influence of local vegetational or topographic conditions becomes less marked, while that of the region or climate gradually increases in effectiveness. It is probably for this reason that the older or lower layers of peat deposits of the Scandinavian countries, of Holland, Germany, Austria, Switzerland, Finland, and Russia appear to have a surprising number of features in common with many of the peat deposits of the northern portion of the United States.

There is the possibility of using the present native vegetation together with plants characteristic of corresponding types of peat material as an indicator and criterion of conditions which may serve for a basis of estimating the agricultural and other possibilities of a peat deposit, provided the relation between the surface vegetation cover, the character of the profile structure, and the nature of the field conditions of the deposit is correctly interpreted. It is necessary to bear in mind, however, that by itself the surface vegetation of any unstable stage in the development of peat deposits can not be regarded as being wholly significant in the determination of the latent possibilities of a peat-land area. Much more importance, especially from the standpoint of interests combining agricultural and technical utilization, should therefore be attached to the profile structure of a peat deposit and to the climatic and geologic differences of peat-land areas.

The arrangement of types and groups of peat material given below is, it should be repeated, a tentative one. It is presented partly from an ecologic point of view and deals, therefore, with a series of peat-forming vegetation units within a set of field conditions such as the writer has described elsewhere for Ohio (5) and Massachusetts (7).

The outstanding physical relationship is the water content of the initial area and its effect upon the character of the series of vegetation stages forming peat and upon the manner of accumulation of plant remains. This fact is of the greatest importance also from an economic point of view in connection with the improvements to be given a peat-land area. It may be accepted as an axiom that undrained deposits of peat contain about 70 to 95 per cent of water, which should not be reduced to less than 65 per cent if the area is to be used for agricultural crops. Drainage and desiccation of peat materials below 60 per cent of water content have been observed to decrease their capacity for disintegration and weathering. The fibrous organic material becomes brittle, inert, maintains its initial appearance for considerable periods of time, and does not become readily nitrified. Certain of the macerated and water-formed types of peat become hard and compact and are not easily penetrated by the roots of crop plants or by water and air. On the other hand, the dewatering of peat materials, especially the macerated types and the well-disintegrated phases of other types, to a water content of approximately 25 to 30 per cent is an essential requirement before they can be used for technical purposes. Desiccation is one of the outstanding problems in connection with the manufacture of peat into a finished product. Thus far, the employment of pressure or of drying other than by the natural action of sun, air, and wind has not proved economically feasible.

It is obvious, therefore, that the utilization of peat deposits for agriculture, for manufacturing purposes, or for a combination of both implies operations which appear in some degree antagonistic. They have been harmonized, however, but only through investigations which give information concerning the quality and quantity of peat materials, the conditions of their formation, and the methods of development required before they can be made available sources of food, power, or finished products. On the continent of Europe industries which are dependent on peat materials for these purposes have been centralized and located in the vicinity of selected deposits situated conveniently with respect to cheap water transportation. Provision is made for contemporaneous and subsequent cultivation with crops for the purpose of operating the peat deposits at their maximum efficiency. Lack of knowledge of the efforts made along these lines by European workers over a period of more than a century is directly responsible for the failure which the attempts in this country have met.

A TENTATIVE CLASSIFICATION OF IMPORTANT TYPES OF PEAT MATERIALS.

In the following classification of peat materials all those data of a physical and chemical nature resulting from investigations of European types of peat have been summarized in Tables I and II which, in the opinion of the writer, may safely be applied to the corresponding types of plant remains found to occur in the peat deposits of the Lake belt, e. g., Ohio (5) and the New England States, e. g., Massachusetts (7), and present also in other States within the glaciated area of North America. For purposes of microscopic identification of plant remains the illustrations given in Früh and Schröter (10) afford an excellent basis for analysis and comparison.

THE AQUATIC GROUP OF PEAT MATERIALS.

Types of peat material (allochthonous) from open water and from shore stages of a vegetation series, of which the plant remains accumulated below the water level.

The peat materials are structureless or coarsely macerated, soft, or compact and sticky, especially in older and deeper strata. They vary in composition, texture, color, etc., according to the depth of water and the character of the water in the initial stages of the area or of the vegetation series; they are largely, though not wholly, composed of the more resistant residues of plant remains, bits of woody and fibrous material, fragments of root and shoot tissue, the outer coats of cellular organisms, and a finely macerated débris as an embedding or binding ground mass which has either partly or wholly lost all vestige of its original organic structure. To this is added in various proportions and from various sources material of plant and animal origin, as well as dust, silt, etc., from the surrounding area, laid down by wind and current.

Several distinct vegetation units which grow either free floating, wholly submerged, or rooted and partly submerged in water may form at any level considerable and extensive layers of material by the constant accretion of plant remains. These peat-forming plants are represented to-day by a great number of species and individuals with semiaquatic habits of growth in fresh and brackish water. Among them are species of Ceratophyllum, Potamogeton, Castalia, Nymphaea, Peltandra, Pontederia, Polygonum, Decodon, and to a smaller extent Typha, Phragmites, and other genera more typical of the later grass and sedge vegetation units. The maximum depth at which a number of the water plants and semiaquatics can grow and accumulate as peat in situ varies with the clearness and temperature of the water, but it rarely exceeds 15 feet (5 meters) below the surface of the water level. Under conditions which accelerate the disintegration of organic material, as in regions having a moderate winter season or which give rise to ground water colored brown from the presence of suspended and dissolved organic débris, the filling of depressions is chiefly from the bordering marsh, bog, or swamp vegetation units.

Three clearly distinguishable types of peat derived from this vegetation are encountered frequently in the same deposit, which differ from one another throughout in texture, color, composition, shrinkage, and other characteristics. In some deposits, however, these distinctions intergrade or the material occurs wedged in as a ground mass among the interstices of woody or fibrous types of peat, or it may be wholly absent.

The peat mass composed of very small particles possesses many of the properties of a colloid and is on that account of the greatest importance in the problem of dewatering the material for the growth of crops or for manufacturing purposes. It is difficult to remove the water content to below 80 per cent, and when dry these types of peat may form gaping cracks and may shrink to one-fourth and even to one-eleventh of their original profile dimension. They are easily tilled, but under cultivation in open crops readily become finely granular, forming a dustlike powder, almost impervious to water, probably caused by the absorption of air. Loss in yields from wind erosion and plant diseases appears to be a detracting feature in this group unless provision is made for windbreaks, irrigation, or for a cropping system that combines or alternates with grasses, small cereals, and broad-leaved crops. The use of sand by mixing it or by covering the peat material with a layer of sand 6 to 8 inches (15 to 20 cm.) thick should be practiced with caution; the method increases in most cases the yield as well as the possibility for growing a greater variety of crops, including truck, cereals, and other staple crops, but losses have been reported due to the selection of unfavorable deposits of material.

Some of the materials are noteworthy because of the relatively high nitrogen content, while others contain more of the waxy, resinous, and other ether and alcohol soluble organic débris (see Table I) from shrubby or herbaceous evergreens. On account of the greater resistance to oxidizing and other agents and to bacterial action, this plant residue disintegrates slowly and tends to accumulate in considerable thicknesses. The high content of organically combined nitrogenous substances is mainly related to the botanical composition of the plant remains and their slow disintegration capacity. They are largely of protein origin, but partly chitinous, "coprogenous," in nature, being skeletal portions and egg cases of insect and other animal life, and to some extent derived from spores and mycelial components. They are extremely resistant to decomposition. A high content of nitrogenous peat substances should not be looked upon necessarily as an important factor in judging the manurial or soil value of peat and muck. Materials from other types of plant remains, though exhibiting smaller values of resistant organic nitrogen, offer greater possibilities for meeting the agricultural and other requirements for soluble nitrogen.

Features such as those described above, especially regarding the ether and alcohol soluble component, make the material valuable for fuel as peat powder or as machine peat in the form of air-dried brick-shaped blocks and for coking or distillation products, provided the ash content is low. They are relatively less desirable for agricultural purposes or for use in gas generators on account of the presence of the resistant components and pitch-yielding and soot-forming by-products.

Frequently the material shows a mottled coloring on account of the presence of sulphur accumulating either in a finely divided form, as small nodules, as crystals of iron and lime compounds, or in organic combination. Ferruginous inclusions are likely to be unavailable or injurious when available; they generally add some shade of red or yellow to the peat material when air dry, or, more rarely, the bluish tint of the phosphatic iron compound "vivianite" (blue iron earth). Contaminations of that kind in fields not suitably drained retard considerably the growth of crops unless the peat material is well aerated, underdrained, limed, or supplied with finely ground rock phosphate and potash-bearing minerals. As mud baths, the saline phases of these types are reported to have proved medicinally valuable, and in European countries they have become the centers of health resorts.

MACERATED TYPE.

"Mudde," "Sapropel," "Gyttja."

Reddish brown to deep brown, more or less macerated plant remains with a fine-grained, oozelike plastic to sticky ground mass in various proportions, which occurs as a filler or binding material in the interstices between the less easily destructible fragments of plant tissue. The material is derived indiscriminately from vegetation units bordering open water. Some of the original identity and form is retained in spores, pollen grains, seeds, leafy and other fragments of pondweed material, bits of smooth and pustulate rootlets, and in the coarser woody, cuticular, or other resistant components. Animal derivatives, such as chitinized skeletal portions and egg cases from insects, are frequent.

The data in Table I are intended to show the marked differences which may result from the presence of ether and alcohol soluble substances, nitrogenous compounds, and products valued in the distillation of peat.

Seasonal admixtures of clay, silt, and sand produce, as a rule, thinly laminated gritty layers, with cleavage planes which often contain leafy impressions, small stems, and other drifted material. The variations in mineral matter constitute phases of the type when the relative proportion, e. g., of iron, sand, silt, or clay, is above 40 per cent.

TABLE I.—*Chemical characteristics of important types of peat material.*

[The data given show the constituents of 100 parts of material, all being on the moisture-free basis except as noted. Abbreviations ("Authority" column), giving credit for data: B=Birk (3), M=Minssen (18), Z=Zailer and Wilk (26–27).]

Types.	Authority.	Organic matter.	Mineral matter (ash).	SiO_2 and insoluble.	N.	P_2O_5.	K_2O.	CaO.	$Fe_2O_3+Al_2O_3$.	SO_3.	Extract.			Elementary analysis.				Coke (charcoal).	Tar and tar water.	Gas.	Calories.
											Ether soluble.	Alcohol soluble.	Total.	C.	H.	O.	N.				
Sec. A.—Aquatic group:																					
1. Macerated type—																					
Level not indicated	M. 72	59.20	40.80	32.26	2.48	......	......	2.34	......	......	0.93	3.00	*a*3.93	......	......	......	......	......	......	......	3,249
	M. 25	93.81	6.19	4.13	.86	0.03	0.01	.46	0.82	0.54	15.62	27.89	*a*43.51	......	......	......	......	......	......	......	6,839
	M. 26	48.53	51.47	45.51	.69	.06	.16	.25	4.82	.30	5.29	10.88	16.17	......	......	......	......	*b*64.20	*b*25.50	*b*10.3	3,371
0 to 0.60 m. level	M. 108	*a*15.22	84.78	76.84	.73	......	......	.40	......	......	.50	3.20	*a*3.70	......	......	......	......	......	......	......	......
2.10 to 3.55 m. level	B. 46	*a*93.57	6.43	......	1.70	......	......	......	......	.48	4.24	11.95	*a*16.19	61.29	5.55	24.55	1.70	*c*40.66	*d*59.34		5,540
3.40 to 3.90 m. level	B. 33	*a*74.64	25.36	......	1.02	......	......	......	......	......	......	......	......	......	......	......	......	*c*36.50	*d*63.50		4,703
5 to 5.65 m. level	B. 26	*a*22.74	77.26	......	.46	......	......	......	......	.40	.86	2.14	*a*3.00	12.94	.95	7.99	.46	*c*51.28	*d*48.72		1,102
2. Colloidal type—																					
Level not indicated	Z.	96.44	3.56	.10	1.03	.04	.04	2.85	.18	.22	2.24	2.85	5.09	55.17	5.11	35.13	1.03	......	......	......	4,934
	Z.	71.71	28.29	......	2.80	......	......	......	......	......	1.57	3.49	5.06	41.87	6.03	21.01	2.80	......	......	......	4,170
	M. 27	70.96	29.04	20.44	3.68	.28	.13	4.58	1.98	1.24	.76	3.93	*a*4.69	......	......	......	......	......	......	......	3,846
20 to 120 cm. level	M. 88	*a*46.46	53.54	49.37	.94	......	......	.35	......	......	2.91	5.89	*a*8.79	......	......	......	......	*b*68.10	*b*20.0	*b*11.9	2,583
0 to 40 cm. level	M. 95	*a*43.96	56.04	3.75	1.98	......	......	30.23	......	......	1.13	2.91	*a*4.04	......	......	......	......	......	......	......	2,886
40 to 100 cm. level	M. 96	*a*48.06	51.94	6.92	2.14	......	......	26.94	......	......	1.21	3.34	*a*4.55	......	......	......	......	......	......	......	2,099
3. Doppleritic type—																					
Level not indicated	Z. 1	96.01	3.99	......	.96	......	......	......	......	......	.49	.85	1.34	53.14	3.96	37.95	.96	......	......	......	4,881
	Z. 2	94.56	5.44	.44	.92	.03	.04	3.89	.35	.23	......	......	......	51.71	3.77	38.16	.92	......	......	......	4,686
Sec. B.—Marsh group:																					
Phragmites communis	Z.	95.80	4.20	1.73	1.46	.16	.38	.73	.33	.50	1.82	9.59	11.42	47.74	6.22	40.38	1.46	......	......	......	4,344
4. Reed-grass type—																					
Fibrous	Z.	85.35	14.65	7.51	1.86	.16	.24	.94	4.17	1.18	.96	1.47	2.43	47.15	5.12	31.22	1.86	......	......	......	4,262
Poorly disintegrated	Z.	88.20	11.80	5.22	2.29	.16	.05	3.02	1.10	1.98	1.08	1.95	3.03	51.38	5.07	29.46	2.29	......	......	......	4,581
Largely disintegrated	Z.	89.54	10.46	3.16	3.07	.17	.03	4.99	.49	1.32	.85	1.70	2.55	52.04	4.58	29.86	3.07	......	......	......	4,691
Wholly disintegrated	Z.	87.15	12.85	8.49	1.88	.09	.26	.45	2.57	.78	3.68	3.97	7.65	52.88	4.65	27.74	1.88	......	......	......	4,754
0 to 20 cm. level	M. 18	92.29	7.71	2.94	2.65	.09	.09	2.63	1.20	.56	1.61	5.65	*a*7.26	......	......	......	......	......	......	......	4,794
20 to 60 cm. level	M. 19	92.71	7.29	.87	2.52	.11	.06	3.86	1.12	1.09	1.27	4.40	*a*5.67	......	......	......	......	*b*41.80	*b*27.0	*b*31.2	4,811
Upper layer	M. 70	*a*70.91	29.09	17.14	2.37	......	2.58	......	......	......	.73	2.18	*a*2.91	......	......	......	......	*b*52.50	*b*29.7	*b*17.8	3,658
Lower layer	M. 71	*a*57.16	42.84	28.17	1.25	......	1.40	......	......	......	.68	2.65	*a*3.33	......	......	......	......	*b*56.50	*b*27.4	*b*16.1	2,958
1.30 to 1.45 m. level	B. 64	96.94	3.06	......	1.70	......	......	......	......	......	......	......	......	......	......	......	......	*c*33.78	*d*66.22		......
Carex stricta	Z.	93.97	6.03	1.95	1.29	.46	1.75	.54	.28	.36	2.09	8.76	10.85	47.79	5.76	39.13	1.29	......	......	......	4,173
5. Sedge type—																					
Fibrous	Z.	96.16	3.84	.59	2.19	.06	.06	1.77	.42	.76	2.27	2.70	4.97	54.58	5.56	33.83	2.19	......	......	......	4,993
Poorly disintegrated	Z.	96.03	3.97	1.56	1.63	.07	.04	.50	1.40	.28	2.96	7.13	10.09	58.55	5.71	30.14	1.63	......	......	......	5,226
Largely disintegrated	Z.	96.49	3.51	.29	2.10	.05	.04	1.52	.99	.46	2.94	4.79	7.73	58.21	5.21	30.97	2.10	......	......	......	5,256

Wholly disintegrated	Z.	94.32	5.68	1.09	1.32	.04	.03	2.53	1.47	.28	6.25	5.02	11.27	58.25	5.63	29.13	1.32	......	......	......	5,314
Level not indicated	M. 46.	[a]94.12	5.88	1.61	3.07	......	......	1.95	......	......	2.58	6.44	[a]9.02	......	......	......	......	......	......	......	5,212
	M. 47.	[a]94.88	5.12	.28	2.75	......	......	2.73	......	......	2.43	6.35	[a]8.78	......	......	......	......	......	......	......	5,235
	M. 66.	[a]79.14	20.86	11.77	2.22	......	......	1.36	......	......	1.51	[a]4.10	[a]5.61	......	......	......	......	......	......	......	4,055
Upper layer	M. 10.	93.88	6.12	1.37	2.94	.20	.06	2.75	1.12	.39	1.03	3.58	[a]4.61	......	......	......	......	[b]60.60	[b]33.7	[b]5.7	5,352
Lower layer	M. 11.	95.26	4.74	.40	2.47	.14	.05	2.60	.80	.45	1.57	4.53	[a]6.10	......	......	......	......	[b]36.90	[b]38.8	[b]24.3	5,387
Hypnum mosses—																					
H. sarmentosum	Z.	97.19	2.81	.95	1.39	.13	.19	.52	.32	.43	1.73	2.96	4.69	50.71	4.66	40.49	1.39	......	......	......	4,477
H. trifarium	Z.	93.84	6.16	2.30	1.23	.42	.28	1.43	.69	.30	1.21	7.44	8.65	45.98	5.62	41.01	1.23	......	......	......	4,157
H. scorpioides	Z.	94.13	5.87	2.64	1.18	.24	.39	1.15	.60	.26	1.48	6.95	8.43	46.30	5.63	41.02	1.18	......	......	......	4,194
6. Brown-moss type—																					
Fibrous	Z.	92.39	7.61	1.46	2.06	.07	.12	3.00	.37	2.25	.94	2.24	3.18	49.73	5.27	35.33	2.06	......	......	......	4,519
Poorly disintegrated	Z.	94.27	5.73	2.73	2.25	.08	.08	.43	1.78	.42	2.37	5.04	7.41	54.82	5.79	31.41	2.25	......	......	......	4,774
Largely disintegrated	Z.	96.68	3.32	.26	2.08	.05	.05	1.14	1.29	.42	2.90	4.23	7.13	56.23	6.08	32.29	2.08	......	......	......	5,041
Sec. C.—Bog group:																					
Sphagnum mosses—																					
S. acutifolium	Z.	97.58	2.42	.84	1.21	.11	.39	.33	.14	.26	1.27	3.87	5.14	48.23	5.33	42.81	1.21	......	......	......	4,521
S. cymbifolium	Z.	97.13	2.87	.81	1.08	.10	.18	.99	.15	.25	.93	2.58	3.51	48.62	5.31	42.12	1.08	......	......	......	4,521
7. Bog-moss type—																					
Fibrous	Z.	98.07	1.93	.94	.89	.06	.11	.28	.27	.15	1.16	2.98	4.14	48.60	5.12	43.46	.89	......	......	......	4,551
Poorly disintegrated	Z.	99.36	.64	.18	.79	.05	.06	.12	.07	.08	2.33	4.24	6.57	50.25	5.27	43.05	.79	......	......	......	4,723
Largely disintegrated	Z.	96.79	3.21	.49	1.35	.05	.05	1.78	.33	.30	4.22	5.50	9.72	55.54	5.46	34.44	1.35	......	......	......	5,283
Wholly disintegrated	Z.	96.08	3.92	3.04	.88	.04	.10	.08	.44	.11	5.58	11.16	16.74	59.82	4.93	30.45	.88	......	......	......	5,447
25 to 45 cm. level	M. 3.	98.19	1.81	.82	.69	.03	.02	.22	.20	.20	2.72	6.48	[a]9.20	......	......	......	......	......	......	......	4,814
50 to 70 cm. level	M. 4.	97.85	2.15	1.17	.64	.04	.03	.20	.22	.18	2.26	5.62	[a]7.88	......	......	......	......	......	......	......	4,706
0 to 30 cm. level	M. 35.	96.83	3.17	1.69	1.37	......	......	.23	......	......	2.68	6.93	[a]9.61	......	......	......	......	......	......	......	4,698
150 to 180 cm. level	M. 40.	[a]98.14	1.86	.57	1.18	......	......	.20	......	......	4.02	9.15	[a]13.17	......	......	......	......	......	......	......	5,104
270 to 300 cm. level	M. 44.	[a]98.30	1.70	.30	1.32	......	......	.27	......	......	6.46	12.55	[a]19.01	......	......	......	......	......	......	......	5,484
0 to 2 m. level	B. 22.	[a]97.40	2.60	......	.96	......	......	......	......	.44	2.37	5.76	[a]8.13	51.40	5.90	38.72	.96	[c]31.67	[d]68.33		4,744
2 to 3 m. level	B. 23.	[a]98.41	1.59	......	1.08	......	......	......	......	.36	6.02	12.72	[a]18.74	57.05	5.49	34.32	1.08	[c]36.03	[d]63.97		5,455
0 to 1.2 m. level	B. 42.	[a]98.44	1.56	......	.65	......	......	......	......	.38	2.96	9.36	[a]13.32	47.52	5.93	43.86	.65	[c]31.06	[d]68.94		4,631
1.45 to 2.10 m. level	B. 45.	[a]97.47	2.53	......	.84	......	......	......	......	.25	5.90	19.60	[a]25.50	55.12	5.47	35.82	.84	[c]40.86	[d]59.32		5,485
Scheuchzeria palustris	Z.	95.95	4.05	.40	1.85	.28	.77	.88	.93	.30	1.74	6.70	8.44	49.07	5.77	39.26	1.85	......	......	......	4,417
8. Arrow-grass type—																					
Poorly disintegrated	Z.	96.20	3.80	2.19	2.62	.31	.04	.24	.77	.11	3.19	4.30	7.49	54.82	5.94	32.82	2.62	......	......	......	4,968
Fiber	Z.	97.76	2.24	.49	2.15	.25	.14	.33	.72	.14	3.16	3.82	6.98	55.22	6.37	34.02	2.15	......	......	......	4,991
Level not indicated	M. 7.	96.43	3.57	1.54	2.09	.19	.07	.56	.91	.16	3.48	8.96	[a]12.44	......	......	......	......	[b]21.30	[b]42.5	[b]36.2	5,034
	M. 48.	[a]95.64	4.36	.99	2.01	......	......	1.80	......	......	4.69	8.90	[a]13.59	......	......	......	......	......	......	......	5,387
	M. 53.	[a]96.01	3.99	.54	1.77	......	......	1.73	......	......	4.47	9.33	[a]14.80	......	......	......	......	......	......	......	5,516
1.25 to 1.45 m. level	B. 59.	[a]99.03	.97	......	1.05	......	......	......	......	......	1.71	6.66	[a]8.37	......	......	......	......	[c]29.56	[d]71.44		......
Eriophorum vaginatum	Z.	98.06	1.94	.41	1.31	.29	.32	.27	.11	.21	1.48	4.65	6.13	49.07	5.68	42.00	1.31	......	......	......	4,473
9. Cotton-grass type—																					
Poorly disintegrated	Z.	99.41	.59	.05	.85	.02	.05	.11	.16	.12	4.69	8.81	13.50	58.98	5.00	34.58	.85	......	......	......	5,188
Fiber	Z.	99.47	.53	.14	1.26	.04	.03	.06	.13	.07	2.79	3.80	6.59	52.64	5.41	40.15	1.26	......	......	......	4,906
Level not indicated	M. 49.	[a]97.02	2.98	1.32	1.33	......	......	.54	......	......	5.08	10.56	[a]15.64	......	......	......	......	......	......	......	5,152
	M. 50.	[a]95.61	4.39	1.60	1.33	......	......	1.37	......	......	7.41	12.88	[a]20.39	......	......	......	......	......	......	......	5,236
	M. 51.	[a]97.50	2.50	.77	1.19	......	......	.62	......	......	4.90	9.84	[a]14.74	......	......	......	......	......	......	......	4,974
Calluna vulgaris	Z.	98.88	1.12	.08	.83	.06	.18	.18	.23	.13	3.99	9.06	13.05	52.95	5.77	38.63	.83	......	......	......	4,805
Calluna vulgaris, whole plants	M. 32.	97.13	2.87	.56	1.04	.23	.51	.67	.10	.23	6.60	24.72	[a]31.32	......	......	......	......	......	......	......	5,295
Vaccinium oxycoccus	Z.	97.70	2.30	......	.76	......	......	......	......	......	2.93	9.02	11.95	52.58	5.57	38.79	.76	......	......	......	4,812

[a] Data interpolated by the writer.

[b] On basis of the air-dry substance.

[c] On basis of the combustible substance.

[d] Volatile matter.

TABLE I.—*Chemical characteristics of important types of peat material*—Continued.

Types.	Authority.	Organic matter.	Mineral matter (ash).	SiO_2 and insoluble.	N.	P_2O_5.	K_2O.	CaO.	Fe_2O_3+ Al_2O_3.	SO_3.	Extract.			Elementary analysis.				Coke (charcoal).	Tar and tar water.	Gas.	Calories.
											Ether soluble.	Alcohol soluble.	Total.	C.	H.	O.	N.				
Sec. C.—Bog group—Cont'd.																					
Vaccinium oxycoccus, whole plants	M. 129	97.37	2.63	0.07	0.91	......	......	0.78	......	......	4.69	22.41	a27.10	......	......	......	......	......	......	......	4,941
Andromeda polifolia	Z.	97.09	2.91	......	.86	......	......	......	......	......	4.47	8.12	12.59	52.33	5.90	38.00	0.86	......	......	......	4,942
Myrica gale	M. 130	98.56	1.44	.06	1.45	......	......	.36	......	......	3.43	17.28	a21.71	......	......	......	......	......	......	......	5,039
10. Bog-shrub type—																					
Heath peat	Z.	89.99	10.01	7.65	2.28	0.22	0.12	0.29	1.42	0.18	2.59	6.30	8.89	51.50	5.06	30.98	2.28	......	......	......	4,690
Level not indicated	M. 1.	95.25	4.75	3.29	1.21	.09	.07	.22	.54	.25	3.30	9.28	a12.58	......	......	......	......	......	......	......	4,879
	M. 2.	93.69	6.31	5.02	1.45	.12	.06	.14	.50	.20	2.73	7.73	a10.46	......	......	......	......	......	......	......	4,812
Sec. D.—Swamp group:																					
Deciduous shrub types	Z.	98.40	1.60	.20	1.37	.04	.05	.54	.34	.32	3.78	5.53	9.31	59.64	4.80	32.59	1.37	......	......	......	5,236
11. Alder type—																					
Surface layer	M. 12.	92.94	7.06	1.86	1.99	.10	.07	2.39	1.21	1.10	2.92	5.74	a8.66	......	......	......	......	b42.30	b31.5	b26.2	5,140
20 to 60 cm. level	M. 14.	91.46	8.54	3.90	2.23	.15	.06	1.77	1.87	.49	3.25	8.48	a11.73	......	......	......	......	......	......	......	4,920
0 to 20 cm. level	M. 15.	83.20	16.80	5.61	3.19	.15	.08	6.35	2.24	2.19	2.68	6.53	a9.21	......	......	......	......	......	......	......	4,371
30 to 60 cm. level	M. 16.	87.20	12.80	1.99	3.09	.11	.08	7.39	1.31	1.64	2.97	6.95	a9.92	......	......	......	......	......	......	......	4,700
3.10 to 3.30 m. level	B. 38.	a80.52	19.48	......	1.31	......	......	......	......	......	......	......	......	......	......	......	......	c34.51	d65.49		......
12. Birch type—																					
Poorly disintegrated	Z.	97.82	2.18	.50	1.60	.05	.05	.53	.43	.49	5.28	6.85	12.13	59.19	5.60	31.42	1.60	......	......	......	5,388
Partly disintegrated	Z.	96.56	3.44	.68	2.29	.14	.03	.39	1.76	.29	5.22	6.69	11.91	59.02	5.77	29.48	2.29	......	......	......	5,477
Level not indicated	M. 8.	97.40	2.60	.50	1.16	.06	.05	.59	.89	.31	3.90	9.14	a13.04	......	......	......	......	......	......	......	5,520
	M. 9.	94.57	5.43	3.15	1.57	.05	.08	.45	.97	.32	6.36	12.58	a18.94	......	......	......	......	......	......	......	5,537
3.15 to 4.25 m. level	B. 24.	a98.20	1.80	......	1.31	......	......	......	......	.35	7.69	16.36	a24.05	57.29	6.01	33.25	1.31	c37.69	d62.31		6,007
13. Deciduous-forest types	Z.	90.69	9.31	......	.90	......	......	......	......	......	5.27	3.84	9.11	52.14	4.54	33.11	.90	......	......	......	4,734
3.70 to 4.60 m. level	B. 12.	a38.74	61.16	......	.58	......	......	......	......	......	......	......	......	......	......	......	......	c44.46	d55.54		......
0.80 to 1.50 m. level	B. 73.	a95.52	4.48	......	1.73	......	......	......	......	.39	4.12	8.75	a12.97	......	......	......	......	c36.69	d63.31		......
14. Coniferous-forest types—																					
4.60 to 6.35 m. level	B. 9.	a33.33	6.67	......	1.59	......	......	......	......	......	......	......	......	......	......	......	......	c38.19	d61.81		......
4.25 to 5 m. level	B. 25.	a98.37	1.63	......	.86	......	......	......	......	.35	10.76	24.22	34.98	66.15	5.93	25.25	.86	c36.48	d63.52		6,615

a Data interpolated by the writer. b On basis of the air-dry substance. c On basis of the combustible substance. d Volatile matter.

Especially interesting in this connection are the marly and diatomaceous accumulations, which on account of their importance are treated here as subtypes.

Characeous subtype.—Structureless, mainly calcareous plant remains, predominantly the deposition of calcium carbonate by green algæ, such as the stoneworts Chara and Nitella; usually comminuted granular fragments, soft, friable, and cream colored to white when pure, yellowish to dark rusty red according to the amount of iron present, grayish brown to black and granular when admixed with herbaceous plant remains.

Shell-marl phases are quite common among various types of peat, but the shell remains from mollusks are not an important factor in the production of the larger or more extensive accumulations of marl. Inclusions, such as calcareous tufa, concretions and nodules caused by blue-green algæ or by bacterial precipitation, and flaky incrustations on semiaquatic plants, mosses, rhizomes of herbaceous plants, and a form of fine tubular material derived from mats of stonewort buried essentially intact, are occasionally found embedded in the macerated types of peat material. Most of the calcareous subtype of plant remains is covered with herbaceous organic matter, but outcrops and layers between beds of peat material are frequent in level valleys.

Extensive deposits of marl and of marly peat materials of other types occur mainly in regions underlain by rock formations containing limestone and in areas where streams, underground and spring waters, or the soil material adjacent to and underneath a peat area are derived from calcareous drift.

Sandy, argillaceous, ferruginous, phosphatic, and peaty marls owe their names to their obvious admixture. Marly phases of peat are as a rule granular, grayish brown to blackish gray in color, and inclined to be high in available nitrogen when under cultivation. To restore a proper balance in the ratio of plant food constituents, they therefore should not be treated with nitrogenous fertilizers. Where the amount of lime is too high, crops tend to become chlorotic and are susceptible to nutritional disturbances.

Beds of pure marl are used in the manufacture of cement, and they furnish lime of value as an agricultural fertilizer.

Diatomaceous subtype.—Structureless, mainly siliceous material from plant remains consisting of diatomaceous shells admixed with a varying proportion of sponge spicules, spore cells, macerated or fibrous plant material, and drift débris; light gray in color and compact but of very little weight in proportion to its air-dry bulk; pervious when free from impurities; blackish gray and plastic to sticky from variations in amounts of well-disintegrated herbaceous aquatic-plant débris; brownish, loose, and mellow when permeated with fibrous roots from grasses, sedges, rushes, and other plants.

These structural and color characteristics are sufficiently well marked in some deposits to constitute three phases in this subtype. It usually forms a well-marked layer at the greater depth of certain basin deposits, but it has been found also as a surface soil material, notably in a number of river valleys in the New England States.

The plant remains are derived from diatoms and other vegetation of microscopic size and simple structure, such as desmids; green algæ and species of Utricularia, Lemna, Riccia, and others are members of the vegetation unit floating freely in the quiet water of ponds and rivers.

Agricultural practices and possibilities are relatively unknown. Species of Calamagrostis, Phalaris, and Carex form the dominant vegetation cover of siliceous deposits on meadows of which the subsurface soil consists of macerated peat materials.

Diatomaceous material has valuable abrasive properties. As "infusorial earth" it is often employed for filtering, insulating, nonconducting, or packing purposes, as an absorbent, and for making protective soundproof envelopes.

COLLOIDAL TYPE.

"Lebermudde," "Saprokol," "Dy."

Finely divided, distinctly gelatinous, plastic organic débris, olive green, yellowish brown, or greenish brown in color; dark gray to blackish brown, hard, and of the consistency of horn when dry. The material is in large part probably a flocculation product rather than the result of chemical reaction or other transformation, since it has been found mainly in basins which are fed by ground waters containing lime in solution or which overlie a calcareous mineral substratum. There appears to be nothing in this type of peat that may be interpreted as of algal origin. The very small particles of plant remains are chiefly fragments from an aquatic vegetation which probably covered the open water area to the exclusion of other plant life. The organic débris seems to be derived largely from light-colored parenchymatous rather than lignitic tissue or waxy and resinous components. Algal filaments are present occasionally, but less abundant than spores, pollen, seeds of water plants, animal ejecta, and other derivatives. Representative data of a chemical nature are given in Table I.

The layer is a transitional one, since in position it occurs more commonly between a lower silty or clayey calcareous mudlike débris and an upper macerated type of peat.

DOPPLERITIC TYPE.

"Dopplerit."

Blackish, structureless, compact, somewhat plastic, and homogeneous débris of mixed origin. An organic complex (organic lime salt; calcic humate), which is partly an end product of disintegration combined with lime and which probably results from a reaction between disintegrating, oozelike and very finely divided fragments of a variety of herbaceous plants, soft, woody tissue, etc., in the presence of ground water from sedimentary limestones or calcareous drift. The type has been found also as a surface layer on peat lands which appear to have been subject to prolonged shallow inundation of water carrying organic débris in suspension. The material is hard when dry, resembling bitumen or lignite, occasionally of a shiny vitreous appearance resembling anthracite; it weathers into angular, irregular-shaped fragments which gradually break down into a fine black dust in overdrained fields. The chemical data in Table I are representative for this type of peat material.

A similar organic complex but mainly ferruginous in character is found in some peat deposits (ferric humate) which appears to arise in a like manner through the action of chalybeate ground waters.

THE MARSH GROUP OF PEAT MATERIALS.

Types of peat material (autochthonous) from meadow stages of a vegetation series in treeless wet places with a water table near or slightly above or below the surface, or partially submerged during part of the year.

The peat materials are essentially fibrous and somewhat felty or matted, formed in the main from roots and rootlets of plants (radicellate peat). Macerated plant remains, seeds, fragments of various tissues, and woody components from shrubs are present in moderate or large quantities according to the degree of inundation of the area.

The types are derived from various vegetation units, such as sedges, reeds, cat-tails, rushes, and grasses. If water-formed layers of peat material and their wind-blown or otherwise transported drift components described above are absent in the profile structure of a peat deposit, it points to the fact that the conditions for the growth of plants and the accumulation of their remains are entirely different from those already discussed. The noteworthy characteristic is the presence of roots which traversed the old soil or the shallow bottom of mud. The network of roots, rootlets, and rhizomes with its entangled matted mass of aerial plant remains also shows that the area had an initial water table near the surface or above it during only a part of the year. To the degree in which the plants form a closed association and the rise of the water table is favorable for their growth, they become buried as extensive or fragmentary layers, essentially intact and fibrous or partially disintegrated. On account of the slight shrinkage of the plant remains, the respective layers which are "built up" in this manner may constitute several feet of a deposit, but further increases in thickness practically cease unless there is considerable disintegration and shrinkage in the material or a rise in the ground-water level from any cause.

When an accumulation of structureless or macerated type of peat material formed in large part by aquatic vegetation units preceded and reached nearly to the water level, peat deposits of this class show as a rule a fibrous matted layer, more or less sharply differentiated in structure from the peat material below it. By the constantly advancing growth of semiaquatic and marsh plants the fibrous materials may gradually extend over the shoaling water, sink as their thickness increases, and thus give rise to filled-in deposits of peat. Water pockets are not uncommon as delimiting strata.

This has an important bearing upon drainage, tillage, and other operations, and upon the possible uses of the land. In planning drainage improvements it is well to remember that deposits not too well drained are safer than those overdrained and that in this respect the distance between ditches and tiles is usually more effective and important than their depth. For areas of greater depths of peat or with poorly disintegrated grades of fibrous peat material it is necessary to anticipate a gradual but certain subsidence to as much as one-fourth of the original thickness. The decrease in the elevation of the surface should be met, therefore, by a provision for deepening the gravity outlet or for drainage by means of pumps.

The marsh types of peat are among the most profitable for agricultural purposes, though several of them indicate in some instances the presence of salts which in sufficient quantity may injure certain cultivated crops. The nature of the mineral subsoil, whether clay or sand, may considerably affect the agricultural value and need for fertilizers, the former responding, it seems, more readily to phosphates, the latter requiring phosphatic and potash manures, and to some extent lime. Marsh or fen types of peat are easily cleared and brought under cultivation, and they are suitable for a variety of crops if carefully drained or if the drainage channels are provided with check gates. Some of the types when overdrained are apt to become brittle and easily break down to light-colored "mull" or granular peat dust. This is especially characteristic of fibrous sedge and of brown-moss (Hypnum) types of peat. Moreover, marked differences may arise from the preponderance of semiaquatic débris undergoing weathering and disintegration. As surface material this blackish fine-grained component is almost impervious to water, probably due to the absorption of air. Windbreaks, preferably of alder, maple, and willow, are necessary to prevent injury from dust storms to seedling crops, but a rotation which includes broad-leafed crops or plants with a fibrous root system to hold the fine-grained débris would be more advantageous and would aid in maintaining a favorable water content at the surface of the soil if irrigation measures are not feasible.

The first crop to be planted deserves, therefore, careful consideration, as it materially affects the disintegration of the plant remains. On poorly disintegrated, fibrous phases of these peat types, potatoes and corn are considered desirable. Where droughts are of rare occurrence not much trouble has been experienced in keeping the ground water too low to injure crops of value in intensive modes of farming. Ferruginous peat material of these types would, however, prove more profitable if under cultivation for hay and pasture.

The value of these types for industrial purposes is dependent on several factors, most important of which are the degree of disintegration, the ash content, and the impurities. The blackish, compact, well-decomposed phases with less than 20 per cent of ash produce less soot or ether and alcohol soluble and pitchy substances than the types of peat which contain the resinous and waxy bodies (see Table I). They are therefore considered preferable for the manufacture of power gas in gas producers where by-products are objectionable and their recovery is not contemplated. As machine peat, thoroughly ground, pulped, and air-dried, they yield a fuel of good quality, generally near 3,500 calories; they are clean to handle, give a relatively intense heat, and are well adapted for smaller manufacturing or farming communities and for domestic uses. The brick-shaped blocks of machine peat that are allowed to air-dry slowly contract into a dense mass covered by a gelatin-like outer layer which is reported to be a hydrocellulose rather than a resinous substance; it renders the machine-made product almost impervious to water, compact, and more resistant to breakage.

The coarser textured, partly fibrous phases of peat appear to be preferable for composting and as a filler for tankage or a base for compounding with fine-ground mineral fertilizers. After excavation the moist peat material should be piled and stored in mounds 20 or 30 feet high and kept under cover if possible for at least six to eight months. During that time the plant remains shrink considerably in volume and undergo a slow internal heating, granulation, and carbonizing process, which may be aided artificially by means of pipes heated with " exhaust " steam. The material has been profitably employed for various uses, including those essential to agriculture and as powdered peat for fuel in blast burners, for firing steam boilers, and for other purposes. It has not yet been shown conclusively that this material will produce nitrates on a large scale if inoculated with nitrifying microorganisms, but culture beds of these types of peat would probably be preferable to other media (5).

REED-GRASS TYPE.

"Phragmites peat," "Schilftorf."

Fibrous peat material, consisting mainly of a network of smooth and pustulate rootlets and stout hollow-stemmed, long, flat-pressed rootstocks (closed at the joints) of the tall reed-grass (*Phragmites communis*); to a less extent are present the plant remains from species of Typha, Phalaris, Glyceria, Carex, or Sparganium. Macerated aquatic débris is found in varying proportions. The material is light yellowish or reddish brown to rusty brown in color; older layers of this type are fairly compact, largely disintegrated, chocolate brown to blackish in color when exposed to the air, and frequently contain charred woody components. They are mottled in appearance when under poor drainage conditions, from infiltration and precipitation of sulphur or iron compounds.

The type is more commonly found in peat deposits of the Central and Middle Western States in layers of considerable thickness. As a peat-forming plant Phragmites is well distributed nearly throughout the United States, tolerant to brackish water and to ground waters which contain a variety of injurious mineral impurities in solution. This renders the surface peat soil liable to saline incrustations drawn from the deeper strata; it tends to retard or prevent the appearance of shrub and tree stages of vegetation and may result in injury to deep-rooting crops when the area is brought under cultivation. On some of the deposits overlying pyritous shale or drift derived from pyrite-bearing rock formations the presence of mineral acids may sensibly diminish the cropping value of the land. The accumulation of iron at the surface may continue, in part replacing the plant remains by ferric compounds and nodular concretions which vary widely in composition.

In Tables I and II have been summarized the more noteworthy data of a physical and chemical nature for this type of peat.

TABLE II.—*Physical characteristics of important types of peat.*

[Data from Zailer and Wilk (26–27).]

Type of peat material.[1]	100 parts of material.						Specific volume weight of material in 1 liter.	
	Moisture free.				Air dry, 25 per cent of water content, absorb—			
	Contain—		Absorb—					
	Organic matter.	Ash.	Water.	Ammonia.	Water.	Ammonia.	Ash content.	Weight.
							Per ct.	*Grams.*
Sec. A.—Aquatic group.								
1. Macerated type	....	....	....	....	....	....	....	....
2. Colloidal type	....	....	....	....	....	....	....	....
3. Doppleritic type	....	....	....	....	....	....	....	....
Sec. B.—Marsh group.								
4. Reed-grass type:								
Phragmites peat (fibrous)	....	....	....	....	....	....	14.65	217
Poorly disintegrated	86.02	13.98	888.1	0.89	666	0.67	11.80	277
Partly disintegrated	86.71	13.29	871.4	.98	653	.74	10.46	417
5. Sedge type:								
Carex peat (fibrous)	....	....	....	....	....	....	3.84	221
Poorly disintegrated	98.27	1.73	1,379.8	2.16	1,035	1.62	3.97	260
Partly disintegrated	96.03	3.97	1,122.4	1.09	841	.82	3.51	288
6. Brown-moss type:								
Hypnum peat (fibrous)	....	....	....	....	....	....	7.61	95
Poorly disintegrated	92.86	7.14	1,506.8	1.22	1,130	.92	5.73	187
Partly disintegrated	94.28	5.72	887.3	2.41	665	1.81	3.32	204
Sec. C.—Bog group.								
7. Bog-moss type:								
Sphagnum peat (fibrous)	97.92	2.08	1,604.2	1.83	1,203	1.37	1.93	88
Poorly disintegrated	99.38	.62	1,635.5	2.64	1,226	1.98	.64	113
Partly disintegrated	95.87	4.13	524.1	2.02	393	1.52	3.21	157
8. Arrow-grass type:								
Scheuchzeria peat	96.16	3.84	1,210.3	2.24	908	1.68	3.80	162
9. Cotton-grass type:								
Eriophorum peat	99.46	.54	974.3	3.46	731	2.60	.59	121
10. Bog-shrub type:								
Heath peat	89.99	10.01	456.0	2.30	342	1.73	10.01	297
Sec. D.—Swamp group.								
11. Alder type:								
Alnus peat; poorly disintegrated	98.35	1.65	564.5	3.83	424	2.87	1.60	287
12. Birch type:								
Betula peat—								
Poorly disintegrated	97.91	2.09	741.8	.97	557	.73	2.18	242
Partly disintegrated	....	....	....	....	....	....	3.44	257
13. Deciduous-forest type	....	....	....	....	....	....	....	....
14. Coniferous-forest type	....	....	....	....	....	....	....	....

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[1] Although no definite data are at present available regarding the physical characteristics of types corresponding to the numbers 1, 2, 3, 13, and 14, the designations of those types are here retained in order to show their relationship in the classification.

SEDGE TYPE.

"Carex peat," "Seggentorf."

(*a*) Light-brown or reddish to dark-brown, fibrous, felty peat material, mainly composed of finely fibrous roots and pustulate rootlets of sedges (*Carex* spp.); more or less uniform in appearance and compact, though porous; often recognized by the presence of the coarser fragments of (triangular) sedge culms; occasionally present are the plant remains and sheathed culms of *Scirpus* spp. or the matted rootstocks of *Juncus* spp. The macerated components from aquatic-vegetation forms and the finely divided débris which contains seeds, pollen, spores, and chitinous and other fragments may be present in varying proportions. Older and more disintegrated layers vary in color from dark brown to brownish black and readily become granular when weathering.

The type is derived from a diffuse stage of sedge marsh or wet meadow, formed in part by rushes and other grasslike plants which are usually present in many peat deposits; they are characterized very frequently by the dense clumps or tussocks of *Carex stricta.* Semiaquatic plants are abundant in the water-logged depressions between the tussocks of sedges, while many herbaceous plants find lodgment in such places on the drier ridges and hummocks.

(*b*) A subtype which is more characteristic in the transition series to the bog group of peat materials consists similarly of a finely fibrous feltlike network from rootlets and underground scale-like leaves and stem portions of a variety of sedges, but usually includes the thickish rootstocks of the buckbean (*Menyanthes* sp.) and the threadlike stems of several bog plants. The material is grayish brown to dark brown in color. It is not easily distinguished from the peat material formed by sedges which occupy open-marsh meadows, except, perhaps, for the occasional resinous and waxy components from bog, heath, and other plants and in the fact that the lower contact layers are often poorly differentiated from the structureless material which formed below the floating sedge mat. Pockets of water are not uncommon.

The plant remains in the bog-sedge subtype show a rather widely varying admixture of sphagnum mosses, cranberry (*Vaccinium* spp.), and other heath plants. Among the sedges *Carex filiformis* is especially active on northern peat-land areas in extending the floating marginal platform of a bog meadow.

The material of poorly disintegrated sedge peat is quite resistant to cutting, plowing, and weathering. It is inclined under excessive drainage to form a mull, or dust, which is peculiar also to a few other types of peat material.

Various physical and chemical data are given in Tables I and II, among which are the striking differences in ether and alcohol soluble extracts.

BROWN-MOSS TYPE.

"Hypnum peat," "Astmoostorf."

Brownish green to drab-colored, light, spongy, matted material, often laminated and porous in appearance, derived mainly from the entire plants of various species of Hypnum mosses or related forms and containing an interbedded admixture, in varying proportions, of finely fibrous rootlets from sedges, etc.

The material disintegrates rather poorly and becomes brittle when overdrained, breaking down into a dust, or mull. Older layers are blackish in color and appear more or less structureless.

The type is more generally a transition feature to the bog group of peat materials; it is found in peat deposits in the Northwestern States and seems to occur there in considerable thicknesses. In the Central and Eastern States it is found only in layers and pockets of irregular size, heavily admixed with the plant remains of species of Carex, Phragmites, and other peat-forming plants. Tables I and II contain the more important physical and chemical data for this type of peat.

THE BOG GROUP OF PEAT MATERIALS.

Types of peat material (autochthonous) from bog-meadow and bog-shrub stages of a vegetation series in wet places, with the water table near or slightly below but rarely above the surface.

The plant remains are characteristically spongy and porous or matted-fibrous to wickerlike peat, somewhat resistant to disintegration, reddish, yellowish, and deep brown in color. The interstices are filled with a macerated débris in varying proportions, often soft and oozelike, in which fragments of cell complexes are usually well enough preserved to be determinable. The resinous constituents and the threadlike rusty brown root fragments of heaths with mycelial fungi are an important factor in lending the specific character and value to this group. In transition stages the finer débris or ground mass forms a considerable portion of the material, with intergradations from structureless plastic-appearing substances discerned with difficulty to clearly recognizable fibrous and woody fragments.

The materials are derived from vegetation units which appear first as scattered, more or less localized plant associations in the marsh stages of a peat deposit. It seems that the succession of marsh to bog has taken place far more frequently than recognized hitherto, since sections through the profile of the lower layers of peat deposits in many localities show clear evidence that the area was formerly occupied by marsh vegetation. Quite similar stratigraphic successions leading from marsh to bog recorded in the peat deposits of European moors have been recognized in this country. In lacustrine deposits, however, bog vegetation appears often as foreland communities and immediately following the semiaquatic stages of a vegetation series after the accumulation of macerated, structureless, water-formed peat has reached nearly to the water level. By means of much-branched interwoven underground stems and fibrous rootlets they border open water or completely surround it as a floating mat, which rises and falls with the seasonal variations in the water table or sinks and becomes buried as a layer of fibrous peat firm enough to support trees.

Bog-plant associations may occur in marshy and wooded areas of valleys and uplands, and they may form definite sedge or "grass" bogs, "moss" bogs, and "heath" bogs under field conditions which inhibit the natural growth of plants other than the bog xerophytes. They are believed to be glacial relicts from a former more general distribution of boreal plants, some of which are represented in Europe and Asia by the same or closely related species. Most of these plants are now confined to an area extending from the north Atlantic to the Mackenzie basin in northern America, in which they attain their best development, and to locations with high atmospheric humidity. In their southern limits of distribution they maintain themselves, it seems, on account of soil conditions which indicate physiological drought as distinguished from physical drought. A discussion of the selective action of the soil stratum which allows bog plants to outgrow others, the effects on certain cultural plants used experimentally, and the possible causes of physiological drought offered in explanation of this fact has been published elsewhere (5; 20).

Where climatic conditions, such as high atmospheric humidity, are especially favorable these plant associations may spread laterally over adjoining land surfaces or move up well-defined slopes of low hills. If the ground water, designated *aerial* as distinguished from *telluric*, rises in proportion, they may react upon other vegetation units. In northern countries of Europe they build up high moors, invade forests, and destroy with their accumulation a part or all of the tree covering.

The peat materials of this group weather slowly if improperly drained, and they require fall plowing and freezing, with frequent packing by heavy rollers, to maintain good tilth and the upward movement of soil water. Of considerable practical moment is the fact that as a general rule the amount of mineral matter is very low in these types and that applications of complete mineral fertilizers and stable manure for inoculation with beneficial soil microorganisms appear to be more effective in establishing a normal balance of plant-food constituents and of bacterial action than in any of the other groups and types of peat material. The cultivation of grasses for hay and pasture or of potatoes as a first crop and corn, preferably for silage purposes, are known to be profitable in the preparation of these peat types for other farming practices.

The shrinkage on dewatering is very much slower than that which occurs when marsh or swamp and aquatic types of peat are subjected to drainage operations. With underlying water-formed plant remains or with water pockets as delimiting layers, the accumulation of bog peat may settle to a considerable extent. A change in the elevation of the gravity outlet or drainage by pumping may later be the only feasible method of relief. It is important, therefore, in designing drainage improvements to anticipate a subsidence of 10 to 25 per cent in the original profile of the deposit. Many bog peat-land areas are now deteriorating because the drainage systems laid out by an earlier generation have not provided for this shrinkage or have been allowed to get out of repair. Where seepage waters and springs arise along the hills bordering the valley or basin, intercepting ditches are extended along the lower edge of the high lands and provision is also made for the annual removal from the drains of any iron or other compound, sand, silt, or invading vegetation. The washing in of mineral impurities should be restricted to the lateral ditches. Saline constituents when present in these types of peat tend to appear and to accumulate at the margins as iron pan and bog iron or in the form of irregular patches of concretions near the ditches or overlying subterranean drainage waters and springs. The ground-water supply, springs, and the mineral subsoil especially require attention in regions of rock formation which contain an excess of soluble salts.

Only the fibrous and poorly disintegrated surface layers of these types are of value as litter and mull if properly dried and shredded (Table I). A rapidly growing industry in Europe is using these plant remains for manufacturing purposes, and they are greatly to be recommended for use in this country. The materials are shredded by simple tearing machinery and passed through rotary sieves to separate the finer mull from the fibrous material, which may be used for bedding live stock, for insulation and packing, in the manufacture of special grades of charcoal for metallurgical purposes, of pulp, pads, fiber, or alcohol (by converting cellulosic components into sugar with diluted sulphuric acid). Shredded peat material from certain species of sphagnum mosses, relatively free from inorganic impurities and of uniform composition, has been used as surgical dressings for wounds and as pads for patients with dysentery on account of its high absorbent value. It is in many respects a good substitute for medicated cotton.

There is an increased demand in Europe for sphagnum mull products, the particles of which are not larger than one-eighth of an inch (3 mm.) in diameter, as an ingredient with molasses in stock feed for fattening purposes and to prevent disorders. Mull from sphagnums as well as from Hypnum mosses and fibrous sedge peat has been employed profitably for packing, as an effective deodorizer and disinfectant for use in receptacles holding waste animal matter, and as an absorbent of gases (Table II) and of the valuable nitrogenous material of stables. The advantages of mull as powdered fuel in blast burners are considerable and of great importance for certain localities. The firing is reported to give a higher fuel efficiency and is relatively smokeless on account of the intimate mixture with the air or gases used. Moreover, there is the possibility of regulating the supply required for complete combustion. The change from oxidizing to reducing flame and from low to very high temperatures can be accomplished quickly.

The poorly disintegrated phases of these types of peat make a very inferior grade of fuel. With the same treatment through pugging or macerating machines, they make a bulky product, light in weight (Table II), dusty and brittle when dry. The well-disintegrated layers of the same plant remains form a much finer grained, uniform, compact mass. The methods and machinery employed for working bog types of peat material, either for use as litter and mull or for heat and power, as machine-shaped air-dried blocks of peat for direct firing, for gas generators, or for distillation products, should therefore be determined in each individual case by a careful preliminary examination. It is obvious that only such deposits permit successful development as provide not only the quantity and quality of peat materials required, but if utilized would not cause an impairment of the land value of the underlying mineral soil. In Europe the most profitable utilization has been a combination of both the technical and the agricultural possibilities to which the peat area may be put during and after the removal of these materials.

BOG-MOSS TYPE.

"Sphagnum peat," "Bleichmoostorf."

Loose, spongy, fibrous or matted-porous, often layered plant remains from the entire plants of different species of sphagnum mosses, usually with an admixture of other bog-plant material; light grayish brown, yellowish, or deep brown in color, according to the degree of disintegration and the species of moss predominating. Where the development of the layer has been gradual and the extension of the mat has become anchored or has been built up, the material consists of poorly disintegrated remains of moss with relatively small amounts of macerated débris and finely fibrous sedge peat. Fragments from heath plants are present in varying quantities.

In the floating-mat phase and in the deeper layers of bog-moss peat which are more advanced in stages of disintegration, the plastic or oozy component occurs in greater abundance. The material is dark brown to blackish in color and shrinks considerably upon drying.

Except in a few Northern States and in Canada the built-up layers of bog-moss peat are rarely of great thickness or purity in plant composition. Other peat-forming plants which usually accompany sphagnum mosses are the cranberry (*Vaccinium* spp.), sundew (*Drosera* spp.), arrow grass (*Scheuchzeria* sp.), cotton grass (*Eriophorum* spp.), *Rynchospora* spp., *Menyanthes* sp., various species of sedge (Carex), and others (5).

The rarity of sphagnum peat is noteworthy and, together with the rather restricted occurrence at the present day of "moss" bogs as compared with sedge or "grass" bogs and "heath" bogs, is interesting, since sphagnum mosses are by many considered to be the starting point and the type plant association of peat deposits.

Considerable work has been done upon the physical and chemical features of this type of peat material, some of which has been summarized in Tables I and II. Other correlative phenomena have been discussed in a previous publication (5, p. 386–392).

ARROW-GRASS TYPE.

"Scheuchzeria peat," "Beisentorf."

COTTON-GRASS TYPE.

"Eriophorum peat," "Wollgrasstorf."

These two types are generally a composite in the peat accumulations of this country. The plant remains appear to be rarely of the thickness of accumulation or homogeneity in composition recorded for European deposits. They are derived from bog plants which associate with or follow closely a zone of the sphagnum-cranberry stage of bogs in our northern peat deposits.

The peat material is rusty to reddish brown, rather coarsely fibrous from plant remains, such as roots, rootlets, leaf bases, and leaf fibers of the wool or cotton grass (*Eriophorum* spp.) and of the arrow grass (*Scheuchzeria* sp.), roughish from the clustering of culms, with varying admixtures of the grayish to dark-brown partially disintegrated sphagnum mosses and the finely threadlike material from cranberry and similar heaths.

The coarser fibered Eriophorum component is quite resistant to disintegration and to cutting processes. When relatively pure in composition Eriophorum peat is deemed of considerable value for textile purposes, the manufacture of cloth, and similar technical uses.

The type of material in which the plant remains from arrow grass preponderate consists of a reddish finely fibrous network of rootlets inclosing thin scalelike leaves and leaf bases of this plant; the peat material is inclined to be brittle when dry and breaks down into mull or peat dust. Chemical and other data are given in Tables I and II.

BOG-SHRUB TYPE.

"Heath peat," "Reisertorf," "Heidetorf."

Reddish to rusty brown wickerlike peat material, partly finely fibrous from rootlets, but with numerous small twigs forming a prominent proportion. The woody fragments are derived from roots, stems, and branches of various bog shrubs, mainly heaths; the macerated ground mass is more or less resinous.

The type is often accompanied by a marked occurrence of highly ferruginous impurities either distributed through the mineral subsoil as a hard impermeable layer or pan or in the form of bog iron on and near the surface. In coastal climates the bog shrubs show beneath the peat material a layer of leached-out whitish or gray sand of varying thickness; underlying it is a characteristic blackish or yellow to rusty brown iron-stained sand, which often contains much of the mineral material and organic colloidal complexes leached from the upper sandy layer. The soils when denuded of their surface covering of peat material appear to be unsuitable for ordinary farming practices unless well handled. Pans, however, are by no means confined to heath bogs; they often occur in forests and on certain marshy and cultivated sandy soils.

The plant remains in heath peat are derived largely from bog shrubs, among which *Andromeda* sp. and *Cassandra* (*Chamaedaphne*) sp. are the most prominent of the ericaceous plants. Other genera, such as Ledum, Vaccinium, Myrica, and Kalmia, are less numerous in individuals and not so general in their distribution as to give rise to specific types of heath peat. In some of the sphagnum-cranberry bog meadows they are present in sufficient numbers to make a dense thicket, thus shading and even destroying the vegetation which covers the ground. The plants spread rapidly by means of long horizontal underground stems, from which arise at intervals erect leafy branches.

Empetrum nigrum and *Calluna vulgaris* occur very rarely on bogs in the United States, but they are among the low evergreen heath shrubs in the bogs of Canada and occur generally on the bogs or high moors of northern European peat deposits.

The chemical and other data cited in Tables I and II relate to heath types of peat on high moors.

THE SWAMP GROUP OF PEAT MATERIALS.

Types of peat material from coniferous trees and from deciduous shrub and tree stages of a vegetation series on a wet substratum with the ground-water table generally below the surface during part of the year, as in bog forests and pond swamps, or partially submerged, as in river and coastal swamps.

The peat materials are characteristically a shrub or a forest litter. The greater proportion consists of woody material; roots, trunks of trees, branches, bark, twigs, etc., in a tangled mass, are in all stages of disintegration and more or less in such a state of preservation as to be determinable. In this are the remains from leaves, ferns, mosses, scales, the rootlets of herbaceous plants, and fungal hyphæ and spores more or less plainly recognizable. The material which fills the interstices consists of semidecayed weathered tissue and granular débris of great variety, comparable in structure with amorphous water-formed peat material, but free from the more obviously transported drift of lacustrine and valley or estuarine deposits.

The most critical factor in origin is the position of the water table. Trees instead of herbs and shrubs take possession of a wet marsh or bog area and gradually become the dominant peat-forming plant cover if the average water level during part of the time is sufficiently far below the surface of peat accumulation to favor weathering and longer periods for decay and for the products brought about by beneficial bacteria and fungi.

The deciduous-tree stage forms the end of the vegetation series; it indicates that an approximate balance is maintained between the amount of peat accumulation and the rise of the water level favorable for the growth of trees and that disintegration and loss of plant remains go on each year at about the same rate as the addition to the deposit made from the mature forest. Only when there is a marked and sufficiently prolonged elevation of the water table from any cause will plants of other vegetation stages reappear, establish themselves, and begin again the accumulation of peat materials.

Many factors may operate to affect the relationship of the water level to the surface, and the resulting types of organic material may vary, therefore, quite as much from climatic and other regional changes as from local features or artificial obstructions. A number of layers of forest litter in a peat deposit containing stumps and roots of trees naturally must be interpreted to indicate an equal number of modified field conditions for peat accumulation.

The presence of roots of trees in the substratum soils of a peat deposit or its bottom muds and the details of stratigraphic sections are features of considerable practical importance. They point to the fact that the area under consideration is in widely different condition for peat deposition and for the disintegration of material from that of filled basins. Originally in a land area with drainage well established the water table became elevated, probably through varying coastal subsidence, accompanied perhaps by irregularities in barrier formation or, more likely, with the accumulation of plant remains, and it practically maintained itself over the area of active peat formation in close adjustment to the growth of the plants holding back the natural drainage. Areas of that class of peat deposits can be drained to the bottom and rarely need the more elaborate drainage measures which aim to reduce the amount of overflow in swamps and marshes resulting from river inundation.

Attention needs to be called to the fact that the dominant timber component alone is not always significant of the capabilities of these types of peat material. The plant remains derived from evergreen shrubs, such as the azalea and rhododendron, or from deciduous undergrowth in forests may alter the value of the material considerably. This is well illustrated in the distinction made by some authors between the "mild humus" characteristic of deciduous forests, well aerated and containing beneficial soil organisms, and the "raw humus" found in coniferous forests in which decay-producing organisms are usually less abundant.

ALDER-WILLOW TYPE.

"Alnus-Salix peat," "Bruchwaldtorf."

BIRCH TYPE.

"Betula peat," "Übergangswaldtorf."

Brown to chocolate-brown peat material, wickerlike in appearance on account of the numerous small twigs and branches of alder (*Alnus* spp.), willow (*Salix* spp.), and other species of deciduous shrubs which form a considerable portion in the fibrous or fragmental plant remains. The woody components often consist of bark and other recognizable, slowly disintegrating parts from birch (*Betula* spp.), but with the exception of the resinous components the material is as a rule relatively soft, easily cut, and tends to become brittle and granular when dry, breaking down into a blackish coarsely grained débris. Material which is well disintegrated or contains a large proportion of plastic ground mass takes on a compact structure and often resembles a hard substance when dry.

The plant remains are derived from shrubs, among which the alders, buttonbushes, and willows are the most common. Birch and ericaceous heath shrubs appear to be more numerous in individuals on peat deposits of the Northern States and in European countries.

The analyses presented in Tables I and II are intended to point out some of the features of practical value to agriculture and to technical interests.

DECIDUOUS-FOREST TYPES.

"Laubwaldtorf."

Loose, mingled débris of partly decayed branches, twigs, bark, and other aerial parts of plants falling to the ground and becoming incorporated in a more or less disintegrated leaf mold, which contains also the remains of herbaceous forms, ferns, and other vegetation growing in a mature hardwood forest. The older material of the layer is usually brownish black, woody, granular, with an abundance of fungal hyphæ. This débris characterizes the more fertile area, a large proportion of which is often brought under cultivation with a small expenditure for fertilizers on account of the finer texture of the well-weathered material and its aerated condition.

The types of most frequent recurrence but which at present must remain without further characterization are the maple-ash-elm (Acer-Fraxinus-Ulmus) type in swamps and bogs of the Central and Northeastern States, often associated with oak (*Quercus* spp.) and basswood (*Tilia* sp.) or with conifers, and the gum-maple (Nyssa-Acer) type in the swamps of the Southeastern States. The data in Table I serve to show the relative value of the European type of deciduous-forest peat.

CONIFEROUS-FOREST TYPES.

"Föhrenwaldtorf."

Reddish brown plant parts from evergreen trees or from a mixed stand of conifers and deciduous forest trees which differ much in their resistance to weathering and decay agencies. The proportion of fibrous or leafy material and of weathered products from shrubs and herbs is quite variable. The ground mass in which the more resistant components are embedded is soft, plastic, and under moderate draining conditions becomes granular rather slowly. In overdrained deposits it dries and shrinks greatly and frequently takes on the consistency of a compact substance, impervious to water, especially when resinous material comprises an important element in the woody components. Experience indicates that coniferous peat materials are likely to be of low value for intensive farming purposes, even several years after clearing.

For each geographical or climatic district there are usually representative tree species which establish themselves, first scattered, then in a zone near the shore of lakes or valley channels, and eventually cover the entire peat-land area. As they grow taller they intercept a large amount of light and thus eliminate and displace the herbaceous and even shrubby undergrowth. The water of a heavy rainfall is held back sometimes to a considerable depth by the dense growth and tangle of fallen vegetation, thus extending the swamp conditions over adjoining areas. The larger number of trees have a shallow superficial root system, which may be removed by various methods of clearing, such as brushing, blasting, pulling, or burning. The plan of "brushing out" the land, plowing shallow the first time, gradually increasing the plowed depth from year to year, and seeding the land to grasses and clover with rye or oats is believed to be the cheapest and best of any of the several methods practiced.

The several types of coniferous forests, such as the tamarack (*Larix* sp.), the northern white cedar or arbor vitae (*Thuja* sp.), and the spruce and pine (*Picea-Pinus* spp.) of northern bogs, the cedar (*Chamaecyparis* sp.) and the cypress (*Taxodium* sp.) of coastal and southeastern swamps, or the mixed type which is characterized by various conifers and deciduous hardwood species, must remain at present without further description. In texture and color the several peat materials appear to have much in common, though they are derived from the dominant species of trees representative of the region. The sharper contrasts are undoubtedly more prominent in the woody and resinous components and other plant remains, as well as in the condition of their decay and in the manner of the accumulation, that is, whether the deposits are the result of river inundation or formed in isolated tracts, fed by seepage and springs, where drainage features are correspondingly very different. Table I contains the more important chemical data for a type of European conifer-forest peat.

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UNITED STATES DEPARTMENT OF AGRICULTURE

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Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

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A CHEMICAL STUDY OF THE RIPENING AND PICKLING OF CALIFORNIA OLIVES.

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OLIVE CULTURE IN CALIFORNIA.

With the single exception of Arizona, olive culture in this country is limited to California, where the tree was introduced in the early days by Spanish priests, the first grove being planted in San Diego in 1769.[2] This origin is recorded in the name of what is to-day the most popular variety, the Mission olive, a descendant of the early plantings. The culture of the olive has extended until there are trees in 38 counties, the important counties being Riverside, Tulare, Tehama, Los Angeles, Butte, Fresno, San Bernardino, and Shasta. In the spring of 1916 a State census showed 834,939 bearing and 515,221 nonbearing trees.[2] In general, the olive-growing sections may be roughly grouped into three districts. The northern district, in the Sacramento Valley, centers in Butte County, with some groves as far south as Sacramento, and many fresh plantings in southern Shasta County, the farthest north. This district is one of the most important, and contains an enormous number of trees not yet bearing. The central district is in the San Joaquin Valley, principally in

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[2] Ann. Rept. Calif. Development Board for 1916. San Francisco, 1917.

Tulare and Fresno counties, centering at Lindsay and Fresno. Recently some very extensive planting has been done in Tulare County. The southern district lies in the territory centering around Los Angeles and San Diego. Although the oldest, it is, or soon will be, surpassed in production by both of the other districts. There are some groves also in a few sheltered valleys along the southern coast, and elsewhere, but they have little commercial importance. Planting is being done in the Imperial Valley. In 1916 the State's estimated yearly production was 1,000,000 gallons of olive oil and 300,000 6-gallon cases of pickled olives.[1] The rapidly growing popularity of the pickled ripe olives and the protection afforded to olive oil by food legislation have given a great impetus to the industry.

VARIETIES OF THE OLIVE GROWN IN CALIFORNIA.

The varieties of olives that have been grown in California are very numerous. The California Agricultural Experiment Station has reported analyses of 57 varieties.[2] The important ones, however, are limited in number, the favorite varieties being, in approximate order of importance, the Mission, Manzanillo, Ascolano, Sevillano, and Nevadillo Blanco.[3] Since the Nevadillo Blanco is more important as an oil olive than for pickling, the observations reported in this bulletin have been limited to the first four named. The Oblitza olive, a large Dalmatian variety, is also used for pickling. The olive was originally grown largely for oil, but more recently the pickling varieties have been in greater demand. The following descriptions of the five varieties are based in part upon material recognized by the industry under the respective names and in part on publications of the University of California.[4]

Mission.—This name denotes the variety derived from the old mission groves, and possibly covers several subvarieties. Of these the common or broad-leaved Mission is the one generally known as Mission. The fruit is of medium to large size, about ten-sixteenths to twelve-sixteenths inch in diameter; ovate, oblique—sometimes very much so—tip rather pointed; fruit variable in size; pit straight or somewhat curved, usually with a sharp point. (Pl. I.)

Manzanillo.—This variety was imported from Spain. It is a medium to large-sized olive, about the same as the Mission, approximately ten-sixteenths to twelve-sixteenths inch in diameter; quite regular, rounded oval, more nearly globular than the Mission, and

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[1] Ann. Rept. Calif. Development Board for 1916. San Francisco, 1917.

[2] Rept. of Work of Agr. Exp. Sta., Univ. Calif., 1898–1901, pp. 263–307. Sacramento, 1902.

[3] E. J. Wickson. The California Fruits and How to Grow Them, pp. 335–350. San Francisco, 1914.

[4] Rept. of Work of Agr. Exp. Sta., Univ. Calif., 1898–1901. Acknowledgments are due F. T. Bioletti for reviewing these descriptions.

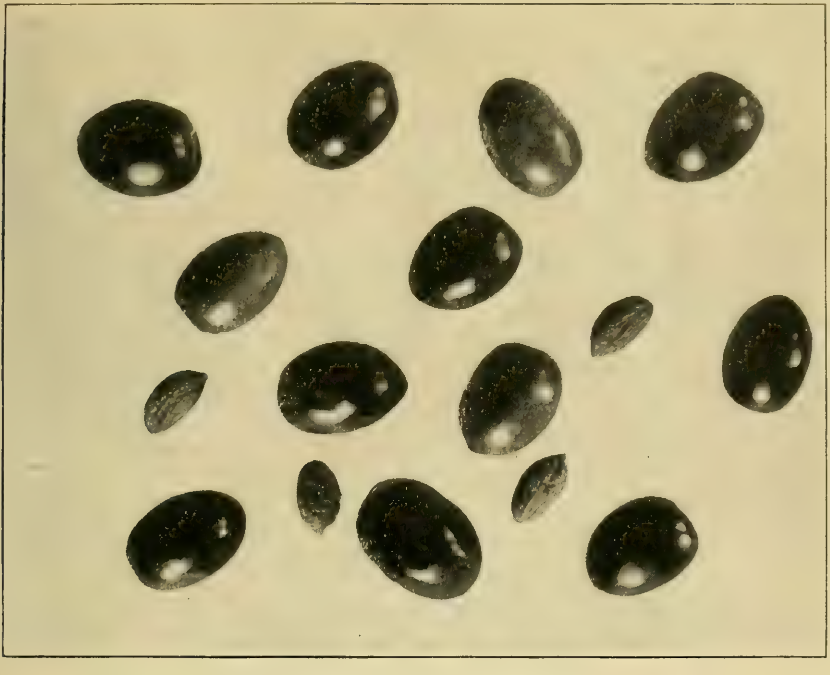

FIG. 1.—MISSION OLIVES, FRESH.

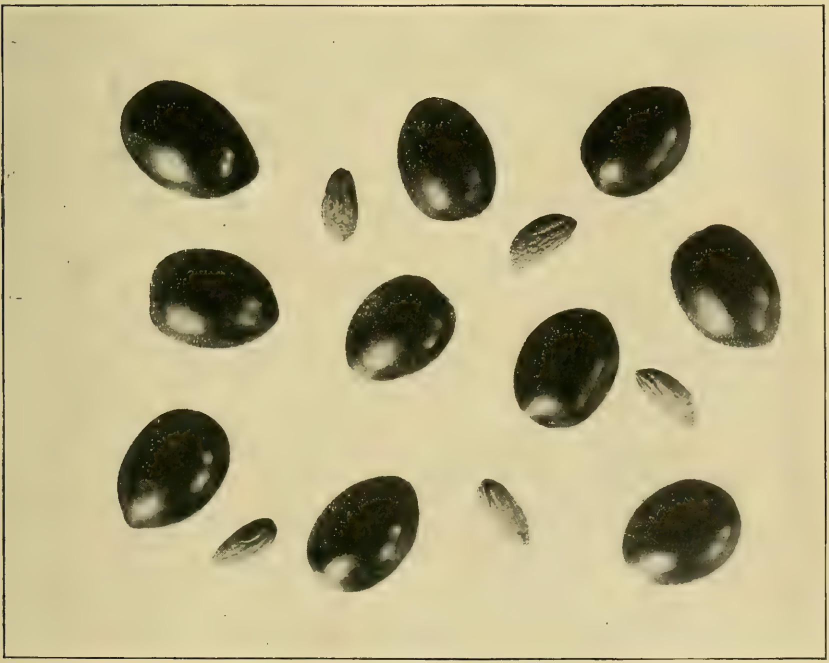

FIG. 2.—MISSION OLIVES, PICKLED.

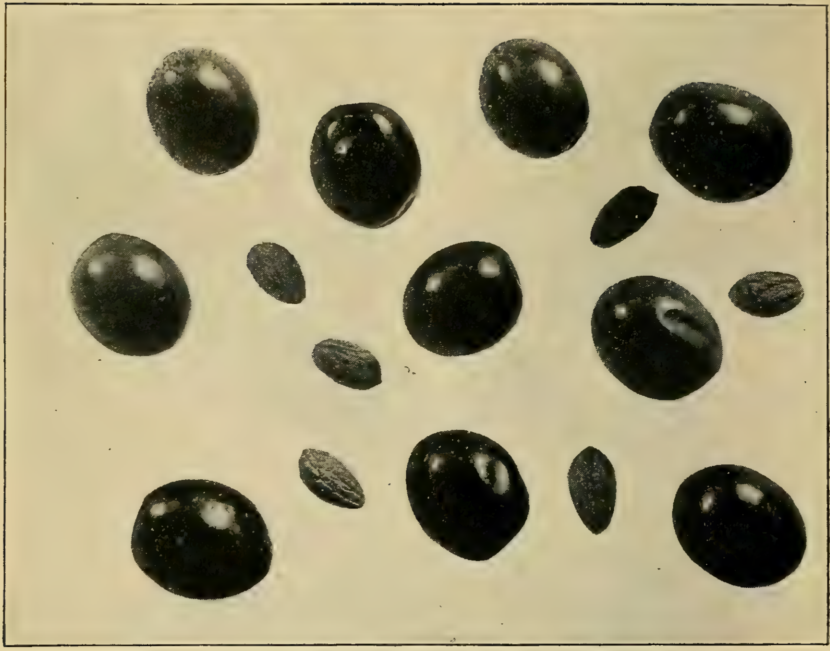

FIG. 1.—MANZANILLO OLIVES, FRESH.

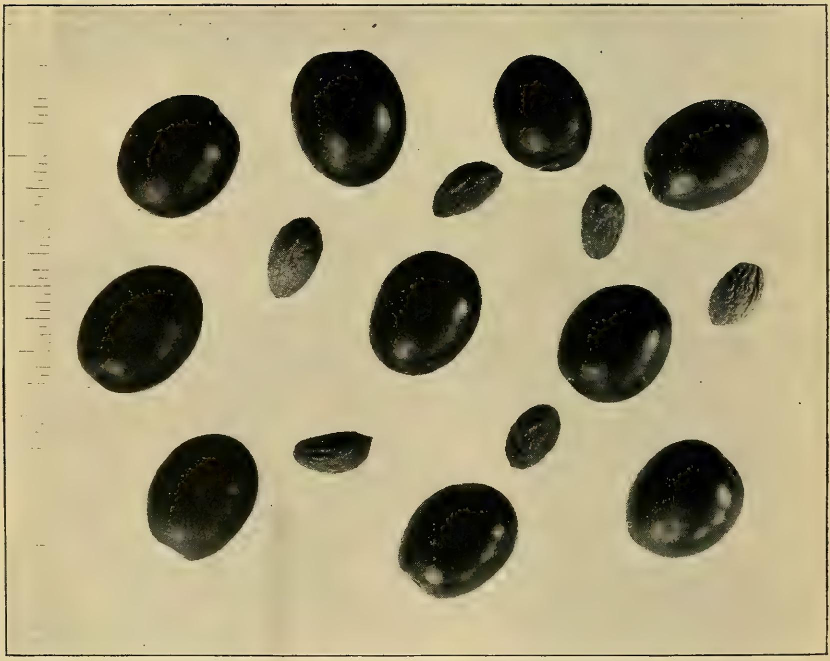

FIG. 2.—MANZANILLO OLIVES, PICKLED.

more rounded on the outer end, and with little indication of a point; pit straight, shorter than the Mission, and with the greatest diameter nearer the apex, often with a short, sharp point at the apex. (Pl. II.)

Ascolano.—This is a very large olive, twelve-sixteenths to eighteen-sixteenths inch in diameter; shape a rounded oval with some indication of a point, resembling an exaggerated Manzanillo; very soft and tender when ripe; pit with a short, sharp point at the apex. (Pl. III.)

Sevillano.—This is also a very large fruit, the largest of the Spanish varieties, and supposed to represent the one exported from Spain as "Queen" olives, from fourteen-sixteenths to eighteen-sixteenths inch in diameter; shape ovate, oblique, resembling a large Mission; very soft and tender when ripe; pit pointed and exceedingly rough, and sometimes with very sharp-pointed projections along its sides. (Pl. IV.)

Nevadillo Blanco.—This variety is small to medium in size, from eight-sixteenths to eleven-sixteenths inch in diameter; relatively long compared to diameter; pit comparatively large, quite curved, distinct veins on surface, and with a short, sharp point at apex.

The size statements in these descriptions refer only to the average run on the tree. Commercially all olives are separated into grades of different sizes.

OLIVE-PICKING SEASON.

The picking season for the olive varies greatly. It is influenced somewhat by variety, but more by locality. In the warm inland valley of the northern district the fruit matures earlier than in the southern portion of the State. The Manzanillo matures somewhat earlier than the Mission. In Butte County, in the northern district, Manzanillos are often picked about the middle of October, Missions late in October or about the first of November, and all varieties are gathered by January 1. In fact, there is danger from frost during December. In the southern district Manzanillos may be picked about November 1 and Missions about November 10. Ascolanos are picked about November 1. All olives are off the trees by February 1 to 15. In some exposed places nearer the coast the seasons may be still later.

CHANGES IN COMPOSITION DURING RIPENING.

Any study of the ripening of the olive must be preceded by a consideration of its constituents. The following are known or have been reported:[1] Fixed oil, protein, mineral matter, mannit (in the immature fruit only), an oxidizing enzyme acting on the oil, the enzyme emulsine and a glucoside "oleuropein," wax, reducing sugar probably dextrose.[2] De Luca[3] and others[2] claim to have isolated mannit from the immature olives, but more recently Hartwich and Uhlmann[1] declared that its presence had not been conclusively shown, and stated that they could not detect it. These authors, who followed microscopically the development from bud to fruit, state that there is no starch in the olive at any stage, with the exception of cells adjoining the stomata. These writers also reported that glucose was present in almost all stages of development, and they believed it to be the substance from which the oil is formed. Of interest is the glucoside discovered by Bourquelot and Vintilesco[2] and named by them "oleuropein." Subsequently[3] they isolated it in a state of comparative purity, finding it powerfully levorotatory and yielding *d*-glucose on hydrolysis by dilute acid or emulsine. They reported it as possessing a strongly bitter taste, which is of special interest, since it thus appears probable that this is the substance, or at least one of the substances, which gives to fresh olives, both in their green and ripe state, their intensely bitter flavor, making it impossible to eat them until the bitter principle has been removed by the pickling process. Also Bourquelot and Vintilesco,[4] by the use of invertine, claim to have demonstrated the probable presence of very small amounts of sucrose in the olive.

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[1] C. Wehmer. Die Pflanzenstoffe, p. 600. Jena, 1911.
[2] Arch. Pharm. (1902), vol. 240, p. 475.
[3] Rend. accad. sci. Napoli (1865), p. 79.

A number of studies on the ripening of the olive in Europe are given in the literature on this subject. De Luca seems to have been the first investigator,[5] beginning in 1861. He showed the increase in the volume and weight of the fruit and that the oil increased gradually from the time the pit was formed. In 1878, Roussille[6] published analyses following the ripening and showing an increase of oil in the fruit flesh from about 1 per cent in July to 34 per cent at the end of November. Funaro published similar analyses,[7] tracing the oil in the fruit flesh from a very low figure in the latter part of July to 27 per cent in late February. Hartwich and Uhlmann, studying fruit from San Remo,[1] distinguished three periods of development. In the first, covering approximately July and August, the pit was forming, and the oil content, on a basis of the whole fruit, increased from about 0.5 per cent to 5 per cent. In the second period, September and October, the pit increased little, while the flesh and oil increased rapidly. In the third period, from October to January, the oil increased slowly until there was 30 per cent in the fruit flesh, which finally declined to nearly 25 per cent in the middle of February. De Luca had noted a similar decrease in oil at the end of the

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[1] Arch. Pharm. (1902), vol. 240, p. 475.

[2] J. pharm. chim. (6th ser.) (1908), vol. 28, p. 303. Compt rend. (1908), vol. 147, p. 533.

[3] J. pharm. chim. (7th ser.) (1910), vol. 1, p. 292.

[4] J. pharm. chim. (6th ser.) (1908), vol. 28, p. 303 (7th ser.) (1910), vol. 1, p. 292.

[5] Rend. accad. sci. Napoli, for 1861 and following years (original source not available).

[6] Compt. rend. (1878), vol. 86, p. 610.

[7] Landw. Vers-Sta. (1880), vol. 25, p. 52.

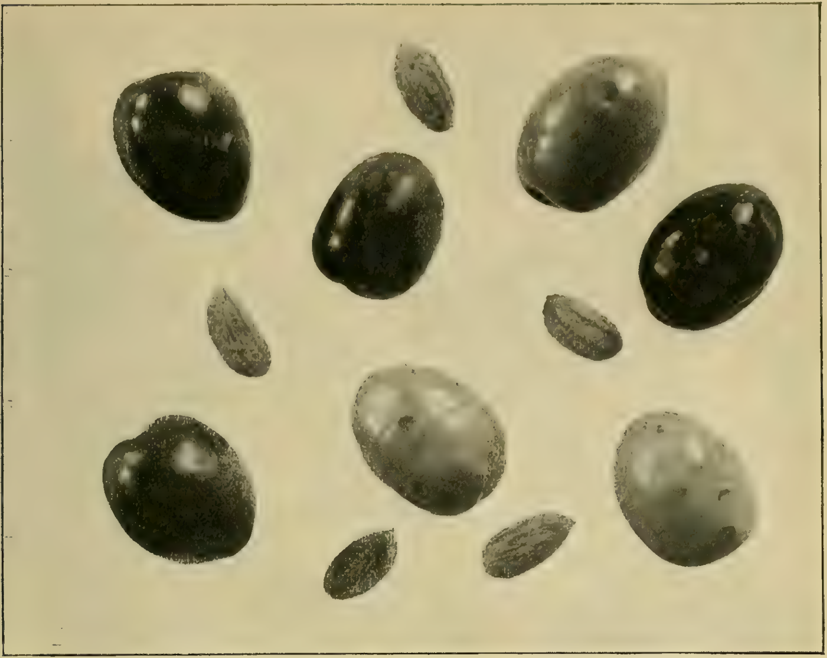


FIG. 1.—ASCOLANO OLIVES, FRESH, RIPE (SOFT IN SPOTS).

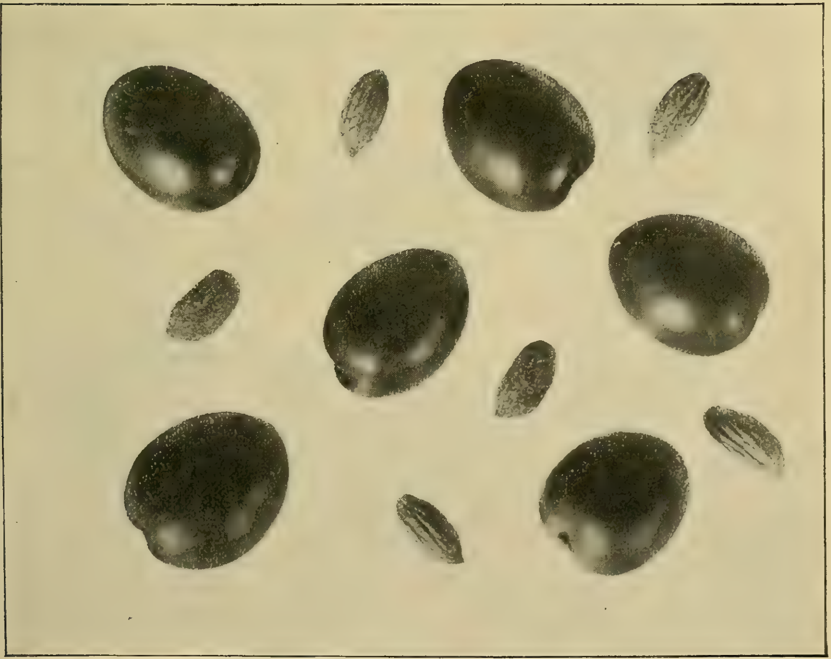
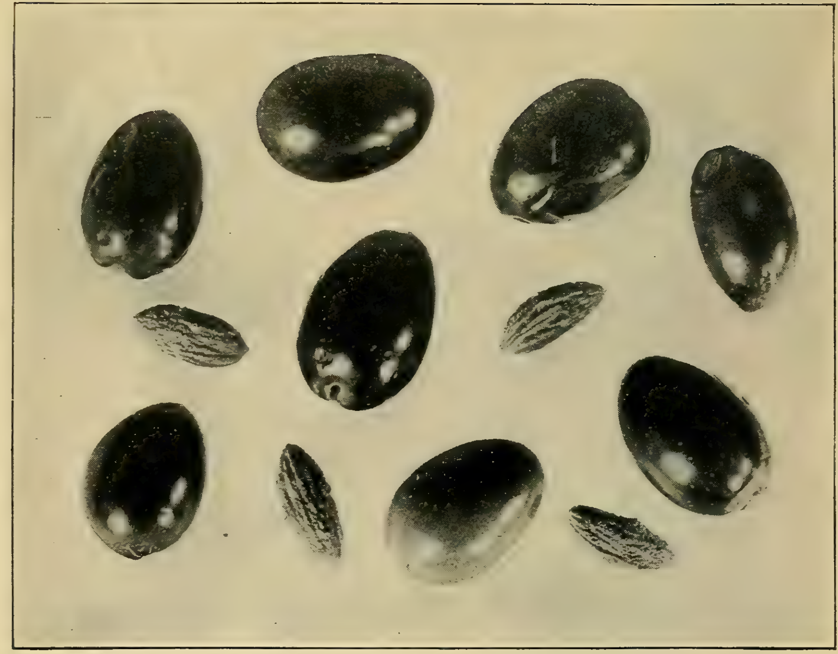
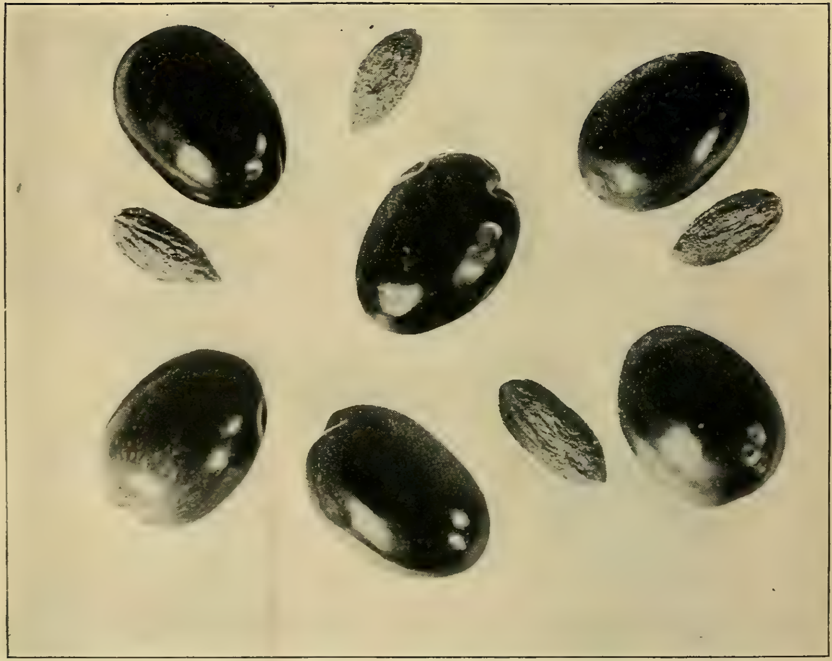


FIG. 2.—ASCOLANO OLIVES, PICKLED.





SEVILLANO OLIVES, FRESH (RIPE AND SOFT).

season. Altogether it is evident that the increase in oil is the striking feature in the development of the fruit.

THE PICKLING OF OLIVES.

There are two methods for rendering edible the fruit of the olive tree, only one of which is commercially valuable. By allowing the olives to soak in brine or fresh water, which is frequently changed, for from 6 weeks to 2 months, the bitter principle is decomposed or removed, and a very palatable article is produced. This method, however, consumes too much time, and the losses due to mold and softening of the fruit bar its general use on a large scale.

Although there are, of course, minor differences in various plants, the general commercial method of pickling ripe olives is as follows: The olives are picked by hand. The buyer gives instructions to the pickers as to the color desired, which varies from "yellow" to red or tinges of red. Usually at least three pickings are necessary to obtain the maximum amount of olives of the desired color. Sometimes the fruit is sent 500 miles to the factory, as from Butte County to San Diego. Such long shipments are made in barrels or wooden vats, the fruit being covered with a weak brine to which is sometimes added a small amount of caustic soda, about one-fourth pound to the gallon.

In the factory the first operation is grading to size, for which purpose several machines have been designed. The most common type of grader consists of a series of vibrating screens with circular holes of gradually increasing size. This gives grades of three or four sizes, the olives smaller than nine-sixteenths inch being generally used for oil. In another common modification the screen bottoms are made of narrow tin strips, the distances between which correspond to the diameter of the holes in the other machine. Both of these machines tend to bruise the fruit somewhat. To avoid such bruising another very simple and satisfactory machine, consisting of a series of rubber-covered rolls which are set at slight angles to each other and inclined, is used. The opening between the rolls is smallest at the top of the incline, and largest at the bottom. The rolls rotate in pairs in opposite directions, so that the inside surfaces turn upward. The olive rolls down the incline, and there is no tendency to mash the olive or bruise it by sudden contact with any sharp edges. When the opening between the rolls becomes greater than the short diameter of the olive it drops through into boxes below, according to its size. The size graduations are usually made on the basis of a difference of about two-sixteenths inch in diameter. There are no recognized trade standards for the size grades or for their commercial designations. Each packer has his own system. The standards in Table 1, based on the best commercial practice, have been suggested by Bioletti.[1]

TABLE 1.—*Standards for size grades.*

Designation.	Size.	Average diameter in sixteenths of an inch.	Average number per pound.			
			Mission.	Sevillano.	Ascolano.	Manzanillo.
Extra large	1	16	35	33	36	39
Large	2	14	52	49	54	58
Medium	3	12	82	78	86	93
Small	4	10	135	142	148	160
Extra small	5	Below 9	?	?	?	?

Many fancy names and symbols are used to designate the various grades. The graded olives are sometimes run over sorting belts to be segregated for color, but this is not common.

After being graded and sorted, the olives are taken to the pickling vats. In the newer factories, these are made of concrete, about 8 by 3 by 2 feet. Similar tanks of redwood are also used, and sometimes circular tanks of redwood, about 8 feet in diameter and from 4 to 5 feet deep. Subject to some variation, the following treatment is applied: A quantity of 1½ to 2 per cent caustic soda solution, in weight about five times that of the olives, is poured over the fruit, and allowed to stand for from 6 to 8 hours, with frequent stirring. This liquor is then drained off, and the olives exposed to the air for 24 hours, with occasional stirring. More of the same or a weaker solution is applied for a similar length of time, and again run off and the fruit aerated. This operation is performed a third time, or until the caustic reaches the pit, as indicated by a darkening of the flesh. The lye solution is then run off, and fresh water added to the vat. The water is changed about every 12 hours until all the lye is washed out. The pickler determines this by taste. Tests of all commercial samples analyzed, with phenolphthalein, show the absence of free alkali or normal carbonates. At this point, salting of the olives is begun by soaking them in solutions of brine of gradually increasing strengths, of about 1, 2, and 4 per cent of salt. Factory control is by means of the salometer, a hydrometer graduated in hundredths from zero in distilled water to 100 in saturated salt solution. Usually the strongest solution employed is approximately 15° on this scale. The olives are soaked about 2 days in each of these different solutions, after which they are canned in a 3 or 4 per cent brine and processed in a water bath. Recently Bioletti and Cruess have proposed preserving in lacquered cans or glass jars without any liquid.[2] It is claimed that the olives thus treated keep their black color better than when brine is used.

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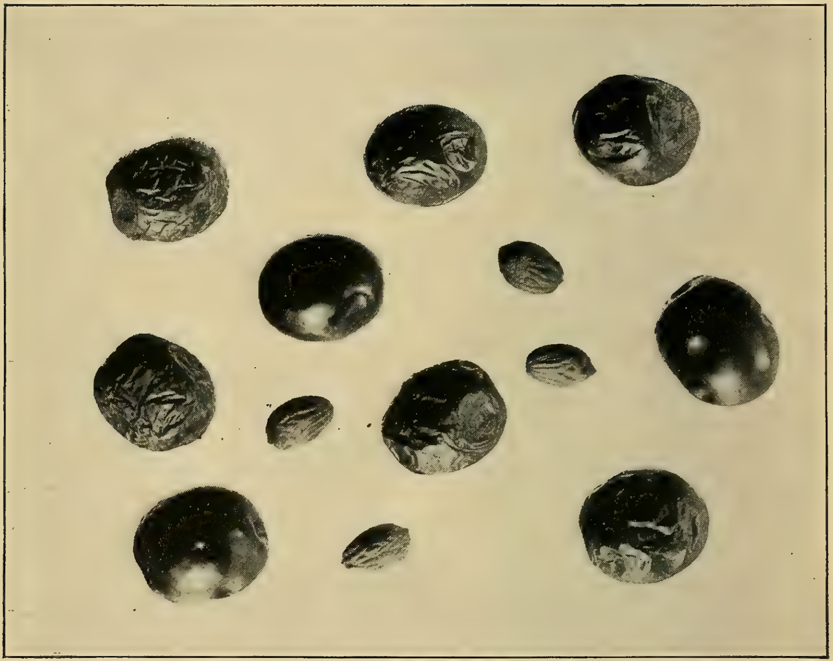
[1] Calif. Agr. Exp. Sta. Bul. 263. The California Olive Association recently has adopted a set of size standards.

[2] Calif. Agr. Exp. Sta. Bul. 289.



MANZANILLO OLIVES, FRESH (ILLUSTRATING THE SHRIVELING DUE TO FROST).

In most factories, after salting, the olives are run over sorting belts, where they are sorted into two or three color grades, and all bruised or injured fruit removed before canning. Patents for assignment to the public have been applied for by Bioletti and Cruess of the California Agricultural Experiment Station at Berkeley, for improvements in olive pickling, which involve the use of heated solutions, with aeration and constant circulation of the solutions.[1] These conditions are obtained in various ways, and it is claimed that the time required is very much shorter, and that a more satisfactory product is obtained. Further details can be had from their descriptions. A point of special interest in pickling the black or ripe olives is that the black color is formed or set by aeration accompanying the alkali treatment.

The pickling of green olives for sale as such is very similar. The olives are picked before any yellow color shows, and they are treated with similar solutions, except that usually only two caustic solutions are used, and the greatest care is taken to protect the olives from exposure to the air, which tends to cause a darkening of the color. The green olive is given an after fermentation under 7 per cent brine which develops its peculiar piquancy.

PURPOSE OF INVESTIGATION.

During the summer and fall of 1914 complaints concerning the pickling of ripe olives in California were received by the Bureau of Chemistry. The charge was made by one or two of the firms engaged in this business that it was becoming a very common practice among the picklers of olives to gather the fruit in a green and immature state and so to manipulate it during the pickling that the color was artificially and unnaturally changed from green to black, the finished product being sold as a ripe olive, to the deception of the consumer and the detriment of the industry. The advantages of this alleged fraudulent practice were stated to be that the fruit could be stripped from the trees in one or, at the most, two pickings, whereas if it were left until it had reached a proper stage of ripeness several pickings would be necessary; also that hard, immature fruit requires less care and skill in pickling, and that early picking does away with the danger of frost damage, especially in the northern districts. It was evident that if there were truth in this statement the practice in question would amount to a coloring or staining by which the inferiority of the immature fruit would be concealed, and that it would be analogous to the coloring of immature oranges by sweating. On examination the question seemed to merit careful study. The investigation here reported was accordingly undertaken to determine whether immature olives were being pickled and sold as ripe, and also whether inferiority was being concealed by a process of coloring.

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[1] Calif. Agr. Exp. Sta. Bull. 289.

PLAN OF INVESTIGATION.

As it does not appear that any systematic study has been made of the ripening of olives in California, the plan of this investigation was first to follow the development of the fruit on marked trees, recording changes of composition and physical characteristics, especially color, in order to establish, if possible, the differences between immature and ripe fruit, and to ascertain how closely the color of the fresh fruit is related to or may indicate maturity. This was done for different varieties and localities, and during successive seasons to show the influence of these factors. In the second place, to make the data applicable to the finished product, different lots of olives were followed through the pickling process to find what changes occur in the composition and color.

FIELD WORK ON FRESH FRUIT.

When the field work was taken up in 1914, the season was too far advanced to permit of any investigation of composition changes during growth. However, in the middle of December, when the fruit certainly could be considered mature in almost all localities and a large part of the picking was completed, series of samples of the most important varieties of olives were collected from the same or neighboring trees in localities in the northern and southern districts. They were analyzed both to afford data on mature fruit and to show, if possible, the relation of color to composition. Also a number of pickling factories were inspected, and men prominent in the industry interviewed.

In the 1915 season the systematic study of the ripening was undertaken in the northern district. Trees of different varieties in different localities were marked and sampled at intervals of practically three weeks from September 15, when the fruit is well formed, to December 15. Since fresh olives are worth from 15 to 20 cents a pound, the value of one tree's crop is so great that no attempt was made to buy outright the whole crop of the trees under observation. As it was considered desirable to follow the development past the regular harvest time, arrangements were made with the growers to leave a certain portion of the tree untouched in the picking. Unfortunately, the picking is done by Japanese, Hindus, and Mexicans, and, in spite of the owners' efforts, many of the trees had been nearly stripped, or at least most of the highly colored fruit had been picked, at the last sampling period. In the northern district the grower generally assumes the frost risk up to December 10, and most of the picking is over by the middle of that month.

The plan of operations for the 1916 season was the same as for that of 1915, except that the trees were more numerous and were scattered over all the important olive districts.

METHODS OF EXAMINATION.

When received at the laboratory the olive samples were immediately examined for color, and, if analysis could not be begun without delay, they were sent to a cold-storage warehouse and stored at about 34° F. until wanted. A slight increase in color was sometimes evident after such storage.

The laboratory methods of examination, as finally adopted, were as follows:

PHYSICAL EXAMINATION.

Record the following: Color, flavor (if pickled), and ease of cleavage of the pulp from the pit; average short diameter in sixteenths of an inch, measuring 50 or 100 olives; number of olives per pound; percentage by weight of pits.

PREPARATION OF SAMPLES FOR CHEMICAL ANALYSIS.

If pickled, pour off the brine and dry the olives with a towel. Reserve the brine for determination of salt. Count out 1 pound of olives, recording the number. Remove the pits with a cherry pitter. Scrub the pits with a brush, dry with a towel, and weigh moist, giving percentage of pits. Pass the flesh of the fruit twice through a meat grinder,[1] and receive in an evaporating dish. Weigh out samples immediately, stirring thoroughly with a spoon before removal of each portion. If desired to analyze the pits, air dry them in a warm place, weigh, and grind as fine as possible in a drug mill.

CHEMICAL ANALYSIS OF FLESH.

Solids.—Weigh out approximately 10 grams in a 2-inch lead capsule containing a teaspoonful of recently ignited sand and a short glass stirring rod. Mix intimately and dry in the water oven, which requires from 5 to 7 hours.

Ether extract.—The material in the lead capsule, including the stirring rod, is crushed and brushed into the inner tube of a Knorr fat extractor, prepared with an asbestos mat about $\frac{1}{8}$ inch thick, previously washed with alcohol and ether, and dried. Cut up the capsule and add to the tube. Extract for about 12 hours with anhydrous ether. Remove the inner tube, let the ether evaporate, grind up the contents in a mortar, return to the tube, and continue extraction for 4 hours longer. Dry the oil to constant weight in the water oven, avoiding undue heating. Periods of from $\frac{1}{2}$ to 1 hour are sufficient.

Protein ($N \times 6.25$).—Weigh out about 10 grams into a 9 cm. filter paper, folded into a cone and placed in a wide-mouth weighing bottle. Transfer the paper and sample to the Kjeldahl flask, and determine nitrogen by the Gunning method, using 40 to 50 cc. of acid, 10 grams of potassium sulphate, and a small crystal of copper sulphate.

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[1] As the skin of the olive is rather tough, the grinder used must be provided with sharp cutting knives.

Ash.—Burn a 10-gram sample in a flat-bottomed platinum dish at a moderate temperature. If necessary to get a clean ash, cool, moisten with water, evaporate, and ignite again, repeating until the carbon is gone.

Alkalinity of ash.—Add 25 cc. of N/10 sulphuric acid to the ash in the dish, heat under a watch glass for a few minutes, and titrate back with N/10 caustic soda, using methyl orange.

Salt-free ash.—In pickled olives, make the solution up to 100 cc., filter, and titrate 25 cc. portions with N/10 silver nitrate and potassium chromate indicator. Express as salt, and calculate salt-free ash.

CHEMICAL ANALYSIS OF PITS.

Determine moisture, ether extract, nitrogen, and ash. For moisture dry 5 grams in a lead capsule, without sand, to constant weight in the water oven, which requires from four to five hours. Extract this residue with anhydrous ether in the Knorr apparatus. This is completed in from six to eight hours. Use 5-gram portions for nitrogen and ash determinations. Calculate the analysis back from the air-dry basis to that of the original moist pits as removed from the olives.

TABLE 2.—*Composition of fresh California olives.*[1]

Sample No.	Source.	Date of collection.	Color.	Whole fruit.												Flesh (water-free basis).			Number per pound.	Average diameter in sixteenths of an inch.
					Composition of flesh.						Composition of pits.									
				Flesh.	Solids.	Oil.	Protein (N x 6.25).	Ash.	Alkalinity No. of ash.[2]	Pits.	Solids.	Oil.	Protein (N x 6.25).	Ash.	Alkalinity No. of ash.[2]	Oil.	Protein (N x 6.25).	Ash.		
	MISSION.	1914.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*		*P. ct.*	*P. ct.*	*P. ct.*		
18205-K	Oroville	Dec. 8	Purple to black	84.0	41.7	24.89	1.55	1.66	8.1	16.0	75.72	2.90	2.62	0.469	11.39	59.7	3.74	3.99	96	12.0
18206-K	do	do	Red	82.3	45.8	27.35	1.73	1.72	11.9	17.7	......	......	......	......	......	59.7	3.74	3.76	128	10.8
18207-K	do	do	Yellowish green	80.0	36.0	20.37	1.27	2.20	7.3	20.0	......	......	......	......	......	56.5	3.54	6.11	125	11.0
18208-K	do	do	Green	77.8	40.2	23.55	1.74	1.70	......	22.2	76.31	3.30	2.70	.554	11.89	58.7	4.32	4.23	162	9.7
18574-K	Sylmar	Dec. 17	Black	85.8	42.8	25.95	1.45	1.88	11.1	14.2	......	......	......	......	......	60.6	3.39	4.39	95	11.6
18574-K	do	do	Red tinge	81.2	35.4	21.21	1.18	1.96	9.6	18.8	......	......	......	......	......	60.0	3.32	5.54	133	10.3
18577-K.	La Mirada	do	Black	87.8	43.1	24.20	1.38	1.60	10.1	12.2	77.76	3.81	2.58	.487	7.35	56.1	3.19	3.71	99	11.4
18577-K	do	do	Green	84.0	34.8	20.68	1.65	1.42	......	16.0	75.94	3.51	2.56	.451	7.37	59.4	4.56	4.08	120	10.9
18579-K	Colton	Dec. 18	Black	87.2	46.6	27.05	1.53	2.11	8.4	12.8	......	......	......	......	......	58.8	3.13	4.53	120	10.7
18581-K	Highlands	do	Purple to black	88.1	38.0	23.05	1.94	1.82	6.5	11.9	......	......	......	......	......	60.6	5.10	4.79	86	11.6
18581-K	do	do	Green	80.8	32.6	18.40	1.66	1.75	......	19.2	......	......	......	......	......	56.5	5.09	5.37	173	10.2
18585-K	Hemet	do	Red	83.8	36.3	21.25	1.63	2.09	......	16.2	......	......	......	......	......	58.5	4.48	5.75	100	11.2
18586-K	Corona	Dec. 19	Purple to black	85.7	46.2	26.38	1.45	2.22	8.7	14.3	......	......	......	......	......	57.1	3.14	4.81	77	12.7
18589-K	Elsinore	do	do	84.3	45.9	29.15	1.59	1.75	9.2	15.7	......	......	......	......	......	63.5	3.50	3.82	83	12.1
18589-K	do	do	Red tinge	79.6	33.3	18.91	1.43	1.68	8.1	20.4	......	......	......	......	......	57.0	4.30	5.05	114	10.5
18592-K	Perris	do	Purple to black	87.6	44.5	26.67	1.63	1.84	8.8	12.4	......	......	......	......	......	60.0	3.64	4.13	76	12.2
	MANZANILLO.																			
18573-K	Sylmar	Dec. 17	Red to purple	88.2	31.1	18.34	1.60	1.72	9.0	11.8	73.05	2.96	2.38	.538	8.03	59.5	5.14	5.56	90	12.1
18573-K	do	do	Green	86.7	29.3	17.64	1.16	1.77	......	13.3	72.28	3.81	2.60	.531	8.93	60.0	3.98	6.05	117	10.9
18578-K	Colton	Dec. 18	Purple to black	88.7	41.1	25.65	1.17	1.92	8.1	11.3	......	......	......	......	......	62.5	2.86	4.80	81	11.5
18578-K	do	do	Green to red	88.4	31.2	20.20	1.13	1.63	......	11.6	......	......	......	......	......	64.8	3.62	5.20	96	11.6
18580-K	Redlands	do	Purple to black	89.9	35.7	23.07	1.34	1.64	7.85	10.1	......	......	......	......	......	64.7	3.76	4.60	83	11.6
18580-K	do	do	Green to red	86.2	29.4	16.80	1.30	1.69	......	13.8	......	......	......	......	......	57.2	4.43	5.75	144	11.3
18583-K	Moreno	do	Purple to black	90.5	33.3	19.93	1.45	1.81	7.2	9.5	......	......	......	......	......	60.0	4.36	5.44	80	10.5
18583-K	do	do	Green to red	87.2	30.0	17.92	1.13	1.79	......	12.8	......	......	......	......	......	59.7	3.75	5.97	137	10.7
18588-K	Elsinore	Dec. 19	Black	87.2	47.2	29.08	1.48	2.21	9.6	12.8	......	......	......	......	......	61.6	3.14	4.68	91	12.4
18588-K	do	do	Green	87.7	32.2	19.30	1.38	1.82	8.5	12.3	......	......	......	......	......	59.9	4.27	5.65	95	12.3

[1] Samples collected in fall of 1914, and analyses made in the San Francisco Food and Drug Inspection Station, by R. S. Hollingshead and W. W. Karnan.

[2] The "alkalinity number of ash" is defined as the number of cubic centimeters of normal acid required to neutralize 1 gram of ash (Buttenberg, Zeit. Nahr. Genussm, vol. 9, p. 142. 1905).

TABLE 2.—*Composition of fresh California olives*—Continued.

Sample No.	Source.	Date of collection.	Color.	Whole fruit.												Flesh (water-free basis).			Number per pound.	Average diameter in sixteenths of an inch.
					Composition of flesh.						Composition of pits.									
				Flesh.	Solids.	Oil.	Protein (N x 6.25).	Ash.	Alkalinity No. of ash.	Pits.	Solids.	Oil.	Protein (N x 6.25).	Ash.	Alkalinity No. of ash.	Oil.	Protein (N x 6.25).	Ash.		
	ASCOLANO.	1914																		
18582-K	Moreno	Dec. 18	Red	89.5	29.0	17.02	1.68	1.70	7.5	10.5	71.69	4.15	2.56	.556	6.51	58.6	5.76	5.86	41	15.4
18582-K	do	do	Green to red	90.4	25.8	15.15	1.21	1.56	......	9.6	74.17	4.61	2.86	.592	7.65	58.7	4.70	6.05	46	14.7
18587-K	Corona	do	Black	88.9	46.8	29.27	1.82	2.15	9.7	11.1	......	......	......	......	......	62.6	3.91	4.60	54	14.7
18587-K	do	do	Green	89.1	36.0	19.80	1.79	1.72	9.8	10.9	......	......	......	......	......	55.0	4.97	4.78	50	15.0
18591-K	Perris	Dec. 19	Red to purple	89.1	41.2	24.79	1.79	1.87	9.7	10.9	......	......	......	......	......	60.2	4.36	4.57	47	15.0
18591-K	do	do	Green	87.7	32.9	18.21	2.03	1.95	9.2	12.3	......	......	......	......	......	55.4	6.18	5.93	62	13.0
	NEVADILLO.																			
18212-K	Oroville	Dec. 9	Black	81.6	37.4	23.04	1.98	2.06	8.8	18.4	......	......	......	......	......	61.6	5.30	5.38	175	9.9
18575-K	Sylmar	Dec. 17	do	86.6	38.7	22.80	1.60	2.36	......	13.4	72.55	3.65	2.93	.548	7.02	59.0	4.14	6.10	145	9.9
18575-K	do	do	Green	85.6	38.4	23.45	1.34	2.23	......	14.4	72.89	3.89	2.77	.649	6.49	61.2	3.50	5.81	175	9.2
18593-K	Highlands	Dec. 19	Purple	86.6	42.9	24.90	1.99	2.32	8.03	13.4	......	......	......	......	......	58.1	4.65	5.41	146	9.6
18594-K	Hemet	do	Yellowish green	82.7	30.7	17.38	1.54	1.97	7.4	17.3	......	......	......	......	......	56.6	5.01	6.43	127	10.8
	COLUMBELLA.																			
18576-K	La Mirada	Dec. 17	Black	87.2	38.1	23.53	2.26	1.62	8.9	12.8	74.91	4.54	2.60	.555	6.66	61.8	5.94	4.25	114	10.7
18576-K	do	do	Green	85.5	31.7	18.97	1.81	1.52	8.0	14.5	74.23	4.22	2.61	.427	7.91	59.9	5.73	4.80	......	......
18590-K	Elsinore	Dec. 19	Red	83.5	43.3	28.64	2.03	1.69	8.4	16.5	......	......	......	......	......	66.1	4.69	3.90	......	......
18590-K	do	do	Green	79.6	38.2	23.00	1.98	1.91	7.6	20.4	......	......	......	......	......	60.3	5.16	5.00	......	......

RESULTS OF EXAMINATION OF FRESH OLIVES.

The data (Table 2) on the samples collected in December, 1914, at which time practically all olives should be ripe, are interesting. These samples, which were carefully selected and segregated on the color basis, ranged from green to purple. The first four samples in the table were picked from the same or adjacent trees in the same grove, as were all the other pairs of samples bearing the same sample number. Size is recorded as number of olives per pound and also in average short diameter in sixteenths of an inch, as both these methods of designation are used commercially. It may be mentioned that diameter and weight are not exactly related, owing principally to differences in shape. Four colors are distinguished—green, yellow, red, and purple. By green is meant "grass" green. The term "yellow," although commonly used by the grower, is a misnomer, as it is a yellowish green, which appears just before the first tinges of red. A study of the various sets of samples in Table 2 coming from the same trees or grove shows that the olives with the more advanced colors usually are larger and heavier than the others, that they have a lower percentage of pits, and, as a rule, are higher in solids in the fruit flesh and contain more oil in the flesh. The oil in the flesh on the dry basis does not appear to be related closely to the color, being frequently nearly the same for the purple and green olives and sometimes higher in the green sample. The amounts of protein and ash in the flesh are roughly equal, fairly uniform, and do not appear to bear any relation to color. The composition of the pits also bears no relation to the colors. In general, then, among olives from the same tree or grove, the ones with deeper

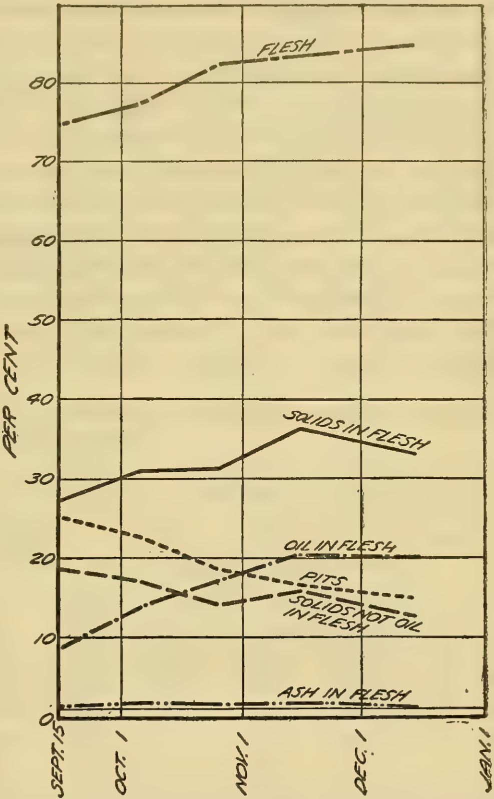

FIG. 1.—Changes in percentage composition of Mission olives occurring during ripening in 1915.

color are the largest and have the most oil and solids in the flesh. This does not hold, however, in comparing olives of the same variety from different groves or localities, as in several instances the green colored fruit has the more oil and solids in the flesh (Samples 18208 and 18581; 18582, 18587, and 18591; 18583 and 18588).

Since the complete data on the series of samples taken from marked trees during the seasons of 1915 and 1916, to show the progressive development of the fruit, are too voluminous to be given here, Table 3 has been compiled from the data secured for a single typical Mission tree in 1915. This table may be taken as an example of the progressive changes observed in the investigation. A clearer idea of the changes which occur during the course of ripening may be obtained from a graphic representation of the data from selected trees, first on the percentage basis, and then on the basis of actual weight changes. Figure 1 shows the percentage changes for a certain Mission tree in 1915, while figure 2 represents the absolute changes in weight of the constituents of 100 olives. The development is indicated by broken curves joining the successive samples from the tree. The same kind of a diagram has been made for a representative Mission tree in 1916 (figs. 3 and 4).

TABLE 3.—*Ripening changes of California olives (typical Mission tree, Butte County, 1915).*

Date.	Fruit flesh.				Number per pound.	Average diameter in sixteenths of an inch.	Pits.	Color.
	Solids.	Ether extract.	Protein (Nx6.25).	Ash.				
1915.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*			*Per cent.*	
Sept. 15	28.58	7.62	1.73	1.76	240	8.5	32.6	Green.
Oct. 6	29.87	11.22	1.73	1.79	226	8.4	29.6	Do.
Oct. 28	32.42	15.46	1.36	1.81	199	8.7	26.4	Green, showing some yellow.
Nov. 15	37.16	18.95	1.52	1.82	192	9.2	24.6	Mainly green; few yellow and red.
Dec. 15	37.43	21.38	1.28	1.80	181	8.8	24.0	Half, yellow with red; half, red to purple.

An examination of figures 1 and 3 shows that the percentage of pits falls as the fruit ripens, while, conversely, that of the flesh rises. The percentage of ash in the flesh remains approximately the same. This is true also of the protein, the representation of which, however, is not included in the charts for the reason that it would practically follow the line for the ash. The protein content was not determined in 1916, as it seemed to have but little significance. It is evident that the percentage of solids not oil in the flesh decreases somewhat during the ripening, the percentage of oil in the flesh increases, with some little irregularity, and appears to drop slightly toward the end of the period in question, while the percentage of solids in the flesh increases with a drop toward the end. Figures 2 and 4, however, give a more truthful idea of the actual progress of the growth of the olive. It is here seen that the actual weight of the pits, which were fully formed at the earliest date, remains practically constant. The weight of ash in the flesh rises very slightly, while that of nonoil solids is very nearly constant, or rises somewhat. The weight of the oil increases markedly in the fore part of the period and slightly near the end, the weight of solids in the flesh following closely the course of the oil. The weight of the flesh and the total weight increase greatly during ripening, with some fluctuations for one of the trees, and follow each other.

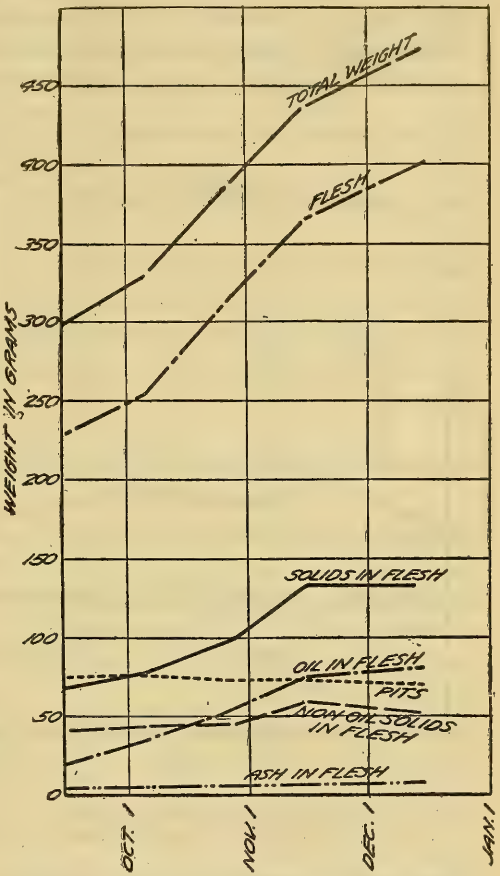

FIG. 2.—Changes in weight of 100 Mission olives occurring during ripening in 1915.

Summarizing these observations, during the ripening, after the pit is formed, the pits remain practically constant while the growth in the flesh continues, and the only constituent of the flesh which increases noticeably, aside from water, is the oil. It thus appears that the amount of oil in the flesh must be the best index of maturity. The same general changes were observed for other trees and other varieties. As the season progressed the olives were found to increase in size, the percentage of pits to decrease, and the oil in the flesh to increase at first rapidly and then more slowly. The protein and ash figures were not significant. A number of minor abnormalities were apparent in the figures obtained. Sometimes the olives appeared to decrease more or less in size, and again the percentages of oil and solids in the flesh declined somewhat. There are several possible explanations for these abnormalities. One is the difficulty experienced in securing representative tree samples at the later periods, from the middle of November on, due to the picking of part of the fruit on the tree (p. 8). Also, when the fruit is struck by a dry north wind it partially shrivels up, which causes a decrease in its weight and an increase in the percentage of the pit, as well as an abnormal increase in the percentage of the oil and solids in the flesh, which, however, drops back when the fruit plumps out again. This actually happened to some of the samples taken in the middle of November, 1915. Another cause is the irrigation of the trees late in the season, as a result of which the fruit increases in size and gains water in the flesh, which produces a slight drop in the percentage of oil and solids in the flesh. It is, however, not impossible that under certain conditions the absolute amount of oil may actually decrease slightly, as noted by Hartwich and Uhlmann and De Luca.

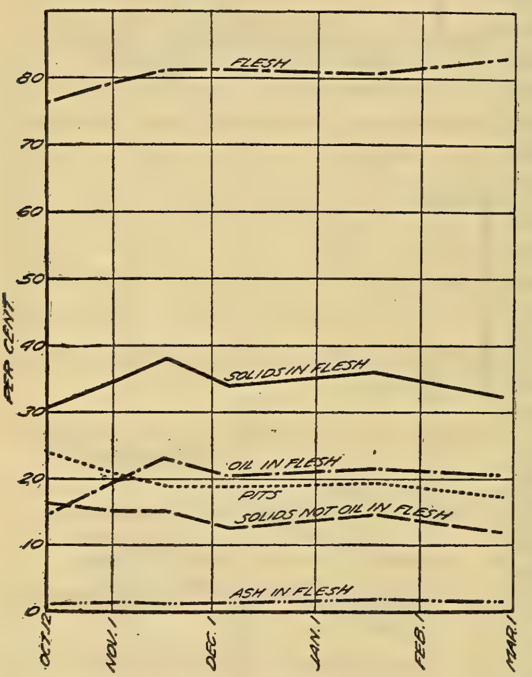

FIG. 3.—Changes in percentage composition of Mission olives occurring during ripening in 1916.

A study of the color changes shows that the olives, which are green in September, begin to color up late in October and in November. Some of the olives may still show a green color in December and January. Calculations of the analyses of the fruit flesh to the moisture-free basis indicated that the percentages of protein and ash decrease somewhat, though not markedly. The oil, of course, increases greatly, approximating in the ripe fruit 60 per cent of the dry substance in the flesh. It was hoped that this might be a valuable factor in judging maturity, but its value is limited, first, because the percentage of oil in the moist flesh is nearly as good an index, and, secondly, because in pickling olives the oil in the flesh on the dry basis increases markedly (p. 20).

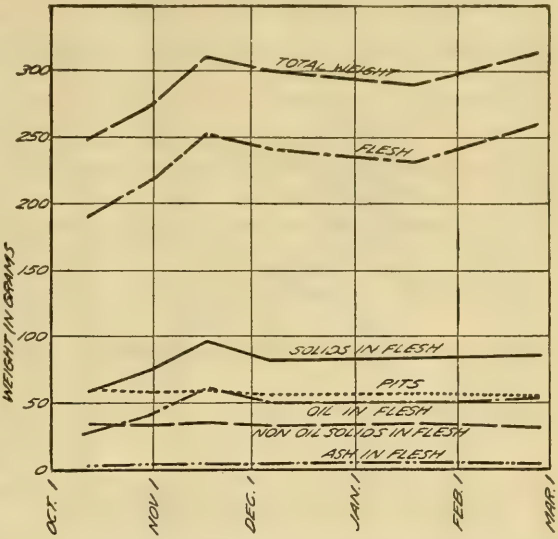

FIG. 4.—Changes in weight of 100 Mission olives occurring during ripening in 1916.

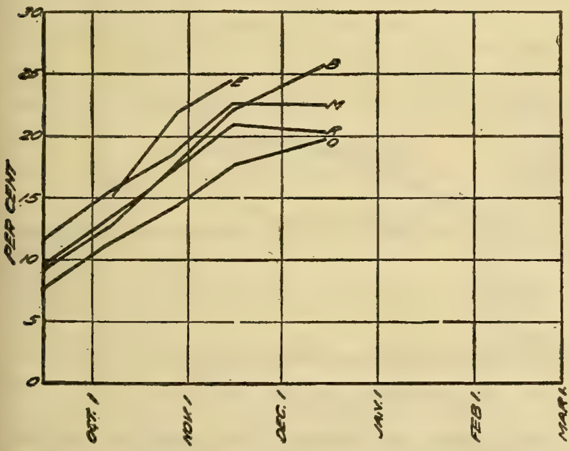

FIG. 5.—Percentage increase in oil content of fruit flesh of Mission olives taken from various groves in 1915.

Since the percentage of oil in the flesh appears to be the most valuable index of maturity, the data bearing on this subject have been represented graphically for the different varieties of olives in figures 5 to 10. Each curve represents the mean of all the trees sampled in a single grove. In figure 5, representing Missions of 1915, northern district, the rapid increase of oil seems to have ended by the middle of November, at which time the fruit could fairly be said to be mature. The poorest of the groves shown had at least 17 per cent of oil in the flesh at that time. Turning to figure 6, Missions of 1916, a great variation is seen. Some of the groves do not merit much consideration. In Grove H, which is in an exposed situation on the coast near Carpenteria, the olives matured very late and never attained the usual oil content for that variety. Grove Fi, which is near by, is more protected. Grove I was very poorly cared for, with trees in bad condition, and is decidedly not normal. Grove S, near Los Angeles, appeared to have attained its maximum oil content on November 13. Although its oil content was much lower than was that of many other groves, this grove was healthy, flourishing, and scientifically cared for. Excluding from consideration Groves H and I, and also probably Fi, none of which is normal, it would seem that the fruit which is poorer in oil may be considered fully mature by November 15, with a minimum of something over 17 per cent of oil in the flesh. From the data now at hand it appears, then, that 17 per cent of oil in the flesh may be taken as a tentative minimum standard for maturity in the case of Mission olives.

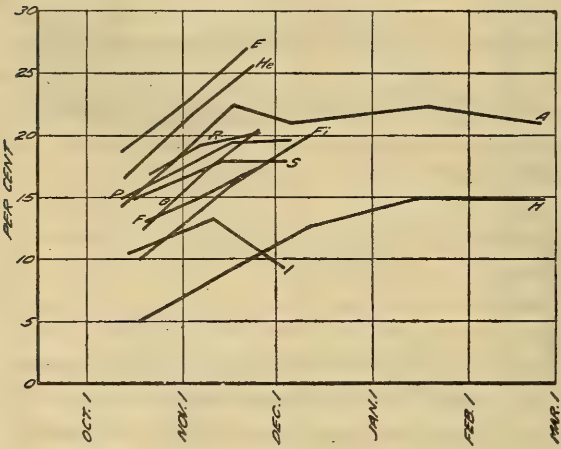

FIG. 6.—Percentage increase in oil content of fruit flesh of Mission olives from various groves in 1916.

The development of the Manzanillo variety is shown in figure 7, in which but few groves are represented, as this olive is not as important as the Mission. The fruit in Grove B appeared subnormal, since it was practically too small to pickle. Compared to the Manzanillos described in Table 2, it seems not unlikely that these crops of 1915 and 1916 may have been unusually low in oil. Analyses in the literature,[1] however, show that the oil in the flesh of this variety averages 2 or 3 per cent less than in the Mission. From the diagram in figure 7 it appears that 15 per cent of oil in the flesh may be taken as a tentative minimum standard for maturity.

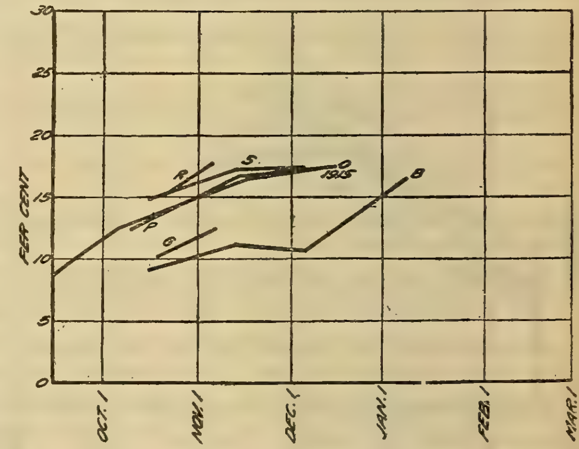

FIG. 7.—Percentage increase in oil content in fruit flesh of Manzanillo olives taken from various groves in 1916.

Of the Sevillano and Ascolano olives represented in figures 8 and 9, it may be said that these are newer varieties, and constitute but a very small percentage of the crop. Few analyses are available on them. Since they become extremely soft when fully mature, they must be picked when in a comparatively immature state, in order to secure a fruit with firm flesh. These varieties, especially the Sevillano, are inferior in flavor, due probably to the lack of oil as pickled, but bring a large price on account of their extraordinary size. When pickled by the California method, they may be said to differ from a green pickled olive in that they are black and do not have the piquant flavor of the green pickle. Considering these facts, it seems impracticable to attempt to set any maturity standard for these olives.

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[1] Rept. of Work of Agr. Exp. Sta., Univ. Calif., 1898–1901, pp. 263–307.

Properly speaking, the Nevadillo olive, one grove of which is represented in figure 10, is an oil olive, although it is sometimes pickled. The curve in this diagram, as well as recorded analyses, indicate that it could easily meet any minimum oil standard set for the Mission olive.

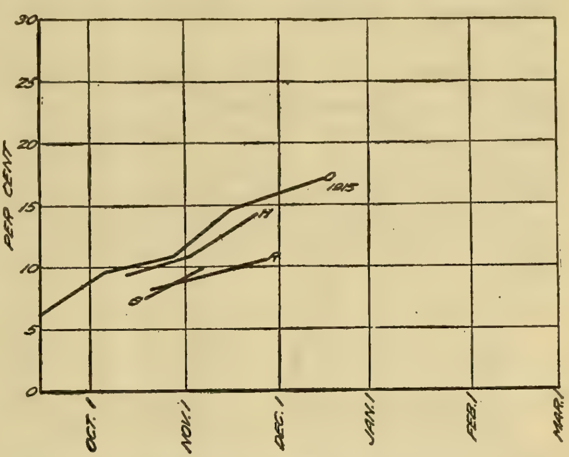

FIG. 8.—Percentage increase in oil content of fruit flesh of Sevillano olives taken from various groves in 1916.

As a matter of interest and for comparison with the data just given, a number of averages for olive varieties,[1] without reference to maturity, are given in Table 4.

TABLE 4.—*Composition of olives of several varieties.*

Variety.	Number samples examined.	Number olives per pound.	Pit.	Oil in flesh.
			Per cent.	*Per cent.*
Mission	112	111.6	17.2	22.51
Manzanillo	38	106.6	14.7	19.73
Nevadillo	57	157.3	17.3	22.92
Ascolano[1]	5	60.6	12.0	18.45
Sevillano[1]	2	36.2	14.5	20.19
Columbella	25	114.6	16.6	19.54

[1] The Ascolano and Sevillano samples must have been quite ripe.

RESULTS OF EXAMINATION OF PICKLED OLIVES.

In 1914, and again in 1916, arrangements were made with a number of picklers for the sampling of marked vats of olives, as received, or before pickling began, and at the end of the process. Much practical information was gathered during this work, in which the picklers, with one exception, cooperated cordially. The data from these experiments are summarized in Table 5. Briefly, the results of these experiments showed that pickling has little effect on the size of the olives or on the percentage of pits. The solids in the flesh, starting with fresh olives, fall 5 or 6 per cent. The oil in the flesh undergoes little change, or decreases very slightly. Some notable exceptions to this rule were undoubtedly due, for the most part, to poor sampling. The addition of salt raises the ash content, but the original salt-free ash is partially leached out. The solids not oil show a notable decrease from the fresh fruit, dropping 5 or 6 per cent, which accounts for a corresponding diminution in total solids. This loss consists mostly of soluble carbohydrates and probably the bitter glucoside. Up to nearly 4.5 per cent reducing sugar, calculated as dextrose, which disappears entirely during pickling, was found in fresh, ripe olives. The protein, which was determined in a few experiments, did not suffer notable change. Because of the loss of solids not oil, the percentage of oil in the flesh on the dry basis is largely increased, rising from about 60 per cent for fresh, ripe fruit to a value 10 or 12 per cent higher after pickling. In some cases the fact that the loss in solids and gain in oil on the dry basis are less is due to the fact that the fruit had been previously shipped or held in brine, causing a loss of solids not oil before the experiment was begun.

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[1] Rept. of Work of Agr. Exp. Sta., Univ. Calif., 1898–1901.

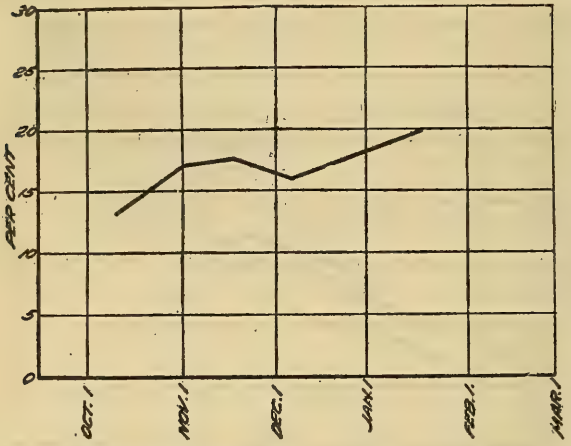

FIG. 9.—Percentage increase in oil content of fruit flesh of Ascolano olives taken from one grove in 1916.

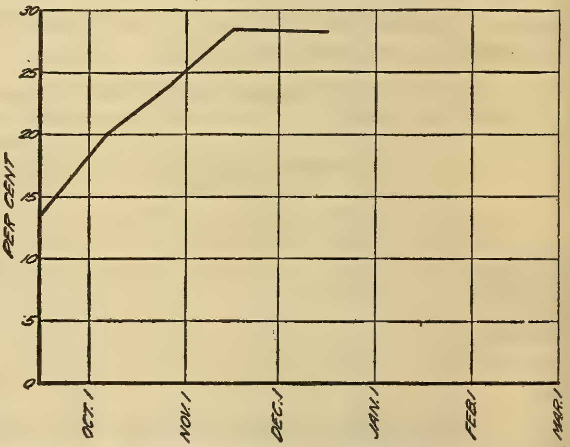

FIG. 10.—Percentage increase in oil content of fruit flesh of Nevadillo olives taken from one grove in 1915.

TABLE 5.—*Effect of pickling on composition of olives.*

Experiment No.	Source and grade.	Date of sampling.		Number per pound		Pits.		Fruit flesh.										Ether extract in fruit flesh (dry basis).		Description and remarks.	
								Solids.		Ether extract.		Ash.		Salt-free ash.		Solids, not oil.					
		Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.
	MISSION OLIVES.																				
						P.c.	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*		
1	Packer A, Sylmar. "Extra fancy."	Nov. 13	Dec. 14	69	69	13.8	14.7	28.80	22.68	17.42	17.47	1.31	1.82	1.07	0.49	11.38	5.21	60.49	77.03	Held in brine 4 days. Color: ⅓, yellow to red; ⅔, red to purple.	Little salt; firm texture; freestone; fair flavor; dark brown, half with purplish bloom.
2	Packer B, Los Angeles. "Extra fancy."	Nov. 14	Dec. 20	93	95	15.0	15.0	32.20	27.84	20.14	21.38	1.00	2.30	....	.56	12.06	6.46	62.55	76.80	Held in water 8 days. Well colored; riper than usually pickled.	Some light brown; rest, nearly black. No bloom. Very tough.
3	Packer B, Los Angeles. "Standard."	Dec. 13	Jan. 8,7	150	144	18.7	18.7	40.17	26.86	24.15	20.89	1.80	2.03	1.64	.55	16.02	5.97	60.15	77.78	Fresh from trees. Color: ⅓, green to yellow; ⅔, yellow to red.	Light to dark brown. Rather soft; fair flavor.
4	Packer C., Bloomington.	Nov. 16	Dec. 8	94	94	14.2	14.7	32.87	27.36	20.82	20.54	1.47	2.61	1.19	.72	12.05	6.82	63.34	75.08	Picked Nov. 11, 1916, Lindsay, Calif. Shipped in brine containing ⅓ pound caustic soda, 1½ pounds salt to 50 gallons. Color: ½, green to red; ½, red to purple.	Color uneven; partly reddish brown; partly with purplish bloom.
5	.....do.............	...do.....	...do.....	101	100	15.0	15.8	32.01	26.73	19.94	19.59	1.40	2.57	1.14	.75	12.07	7.14	62.29	73.29	Same as Exp. 4. Color: ⅔, green to yellow; ⅓, yellow to red.	Brown to nearly black, little or no purple bloom. Texture and flavor fair.
6	Packer D, Los Angeles.	Nov. 29	Jan.17,7	123	121	15.6	16.3	29.16	23.70	17.77	17.55	1.20	2.01	....	.41	11.89	6.15	60.94	74.05	Apparently shipped in water. Color: ⅔, green to yellow; ⅓, yellow to red.	Dark brown; some purplish bloom. Fair flavor.
7	Packer E, Oroville.	Dec. 8,4	Jan. 6,5	110	115	17.7	17.8	29.5	27.9	20.07	19.90	.97	3.07	....	.70	9.43	8.0	68.2	71.3	Held several days in very weak caustic soda. Color quite uniformly green tinges of red.	Color varies from black to yellow, with many brown. Very firm on pit.
8	.....do.............	...do.....	...do.....	72	76	13.7	14.4	31.8	29.0	21.40	21.65	1.21	3.38	....	.64	10.40	7.35	67.3	74.7	Color uniformly black. Held several days in very weak caustic soda.	Color varies from yellow or tan to purplish black. Appearance similar to Exp. 7, except free on pit.

TABLE 5.—*Effect of pickling on composition of olives*—Continued.

Experiment No.	Source and grade.	Date of sampling.		Number per pound		Pits.		Fruit flesh.										Ether extract in fruit flesh (dry basis).		Description and remarks.	
								Solids.		Ether extract.		Ash.		Salt-free ash.		Solids, not oil.					
		Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.
9	Packer F, Oroville.	Dec. 9, 4	Jan. 9, 5	79	98	*P.c.* 15.7	*P.c.* 16.8	*P.c.* 38.6	*P.c.* 30.6	*P.c.* 22.38	*P.c.* 23.65	*P.c.* 1.65	*P.c.* 3.06	*P.c.*	*P.c.* 0.88	*P.c.* 16.22	*P.c.* 6.95	*P.c.* 58.0	*P.c.* 77.3	Color, fairly uniform red. Held in water several days.	Chocolate to purple black.
	Average.....	....	....	99	101	15.5	16.0	32.79	26.96	20.45	20.29	1.33	2.54	....	.63	12.39	6.67	62.58	75.26		
	MANZANILLO OLIVES.																				
10	Packer G, San Diego. Size No. 2.	Nov. 2	Nov. 17	78	74	11.9	10.9	25.44	18.81	14.23	12.65	1.82	2.86	0.75	.57	11.11	6.16	56.05	67.25	Held in brine 1 month. Color: ½, yellow to red; ½, green to yellow; red olives show brownish tinge.	Purplish bloom. Clingstone; leathery texture; quite salty; poor flavor.
11	Packer H, Fresno. "Special."	Nov. 6	Nov. 27	71	67	10.9	11.0	27.57	20.48	16.67	14.14	1.74	2.39	1.37	.57	10.90	6.34	60.47	69.05	Color: ⅓, green to yellow; ⅔, yellow to red. Held in brine 10 days.	Purplish bloom. Clingstone; leathery texture; quite salty.
12	Packer H, Fresno. Size No. 1.	...do.....	...do.....	65	64	9.9	9.8	26.91	19.84	15.82	13.56	1.13	2.95	.91	.45	11.09	6.28	58.79	68.35	Color: ½, green to yellow; ½, yellow to red. Held in brine 10 days.	Purplish bloom. Fairly freestone; slightly leathery; salty flavor.
13	Packer I, Porterville. Size No. 1.	Nov. 8	Nov. 28	64	62	10.6	10.3	26.56	21.76	15.91	14.79	.96	2.87	....	.59	10.65	6.97	59.90	67.97	Color: ½, green to red; ½, red. Held in water 1 week.	Brown with purplish bloom. Clingstone; flavor poor; texture variable.
14	Packer J, Pacoima.	Nov. 13	Jan. 9, 7	75	81	9.8	10.9	18.70	18.82	11.42	12.79	.84	2.58	....	.56	7.28	6.03	61.07	67.96	Color: ⅓, green to yellow; ⅔, yellow to red. Probably held in water.	Half dark brown, ½ with purplish bloom. Texture good; flavor poor.
15	Packer B, Los Angeles.	Nov. 14	Dec. 13	77	72	10.5	10.5	20.73	18.39	12.51	13.00	.88	2.62	....	.51	8.22	5.39	60.35	70.69	Color: ⅔, green to yellow; ⅓, yellow to red. Held in water 2 days.	Brown to purplish brown. Firm texture; good flavor.
16	Packer C, Bloomington.	Nov. 16	Dec. 8	98	92	11.2	11.3	24.70	21.65	15.71	15.51	1.12	2.19	0.86	.68	8.99	6.14	63.60	71.64	Picked Nov. 11, 1916, Lindsay, Calif. Shipped same as Exp. 4. Color: ½, green to yellow; ½, yellow to red.	Color irregular, partly reddish brown, ⅓ with purplish bloom.

17	Packer K, San Diego.	Nov. 17	Dec. 20	69	69	10.7	10.9	25.50	20.94	14.85	14.61	2.83	3.02	.77	.46	10.65	6.33	58.23	69.78	Picked Oct. 27, 1916, Fresno, Calif. Shipped in brine, ½ pound salt per gallon. Color: Green, with red tinges when picked.	Half brown, ½ with purplish bloom. Soft texture.
	Average			74	73	10.7	10.7	24.51	20.08	14.64	13.88	1.41	2.68	....	.55	9.86	6.20	59.81	69.08		
	ASCOLANO OLIVES.																				
18	Packer C, Bloomington.	Dec. 8	Jan. 15,7	60	56	11.6	11.2	22.78	19.85	13.66	13.67	1.13	1.66	1.03	.58	9.12	6.18	59.96	68.87	From Oroville district. Held in weak brine 1 month. Color probably green.	Some brown; most with purplish bloom. Texture very firm.
	SEVILLANO OLIVES.																				
19	Packer C, Bloomington.	...do.....	...do.....	41	36	12.5	11.5	17.79	15.09	10.93	10.27	.93	1.32	.78	.65	6.86	4.82	61.44	68.06	Color: ¾, green to yellow; ¼, yellow to red. Held in weak brine.	Dark brown. Texture very soft; flavor very poor.

The color changes are remarkable and important. Green or yellow colored olives, by suitable manipulation, emerged from the process with a uniform, pleasing black color. In fact, green-colored olives have a tendency to yield a blacker final product than purple olives. The best color, however, is probably developed in olives showing some red at first. Purple olives tend to lose their color and come out brown or even tan. The black color is developed by aeration accompanying alkali treatment, and there seems reason to suspect that the final black is due not to the original pigment substance but to something developed during the pickling. The original colors turn a dirty brown or tan in the first caustic liquor. One of the factories has experimented with the addition of ferrous sulphate to the wash waters, with the idea of fixing the color. The pits of the olives so treated have a marked black color. The results of this treatment have been unsatisfactory.

SUMMARY.

The results of the investigation here reported indicate that the best index of maturity for olives, both fresh and pickled, is the percentage of oil in the fruit flesh. Allowance, of course, must be made for variations due to the variety of the olives and the locality in which they are grown. A minimum oil content of 17 per cent in the flesh is offered as a tentative standard of maturity for Mission olives and other common varieties, except the Manzanillo, Ascolano, and Sevillano. A minimum oil content of 15 per cent is recommended as a tentative standard for Manzanillo olives. No standards for maturity are recommended for the large-fruited olives, Ascolano and Sevillano, which must be gathered when relatively immature. These olives, however, should not be sold under the designation "ripe."

Because of the great variations noted in the composition of olives of the same variety grown in different localities, it probably will never be practicable to set definite and hard fixed minima for oil in mature olives, and the proposed standards must be applied with caution.

It was found that some of the abuses, the report of which led to this investigation, did exist, immature olives having often been pickled and colored to simulate pickled ripe olives. The data here given will make possible the detection of gross frauds of this nature.

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Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

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A STUDY OF THE BEHAVIOR OF BEES IN COLONIES AFFECTED BY EUROPEAN FOULBROOD[1]

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INTRODUCTION

The brood diseases of bees cause annually large losses of bees and consequently of the honey crop. The predominant attitude among beekeepers has long been how best to eradicate an invading bee disease after the attack has been made. They depend upon this procedure, because little is known with any degree of certainty concerning the natural conditions which might prevent or control the onslaught of the disease. As a result of this attitude, much more importance has been placed on the significance of apiary inspection and police-power laws and of purely remedial treatment, the reasons for which in many cases are imperfectly understood. But the old adage "an ounce of prevention is worth a pound of cure" has yet to be refuted, particularly with regard to beekeeping. In the realm of human

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[1] A series of investigations was started in the spring and summer of 1918 by the Office of Bee-Culture Investigations, Bureau of Entomology, for the purpose of making an intensive study of European foulbrood of bees, primarily from the standpoint of insect behavior in relation to the disease, correlated with the facts and practical observations already known to the beekeeper. This paper, which was submitted for publication January 13, 1919, is a preliminary report on the beginning of the investigation.

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medicine, for the last two decades at least, this precept has been gaining strength so that to-day preventive medicine stands on a par with, if not above, most of the other branches of medicine. Why is it not logical to apply this principle to the control of bee diseases?

Ever since European foulbrood of bees was first recognized (in 1894), in New York State, as a distinct brood disease, there have been much controversy and speculation concerning the etiology of the disease, the means of transmission, the method of spread, and, resulting therefrom, the question of control. From the laboratory standpoint, the etiology of the disease has been worked out quite definitely bacteriologically (12)[1]. But as yet *Bacillus pluton*, the accepted cause of European foulbrood, never has been grown in pure culture on artificial media, although it has been definitely identified as the cause of the disease. This precludes any further advance along this line of attack for the time being.

From the side of practical experience, there have been recorded large numbers of observations, many of them of a similar nature. These observations have led to many accepted practices, as, for instance, the use of Italian bees and strong colonies in combating the disease. Although the weight of numbers tends to give substantiation to observations, the scientific explanation of how these things are true never has been studied carefully and coordinated with the practical side into an epidemiological study of the colony under disease conditions in European foulbrood.

The history of bee diseases has developed mainly along two lines. The scientific side has been concerned principally with determining the causes of the various diseases microbiologically, the method of diagnosis, and conclusively differentiating them. These facts have been described sufficiently in various bulletins of the Bureau of Entomology and will not be discussed here. From the practical side, countless observations have been recorded, largely in the bee journals, in which various manifestations of the disease and experiences with methods of treatment have been discussed. But in all this literature, particularly with regard to European foulbrood, there are few observations on the disease and on the behavior of the bees in relation to it beyond simple description of symptoms.

Early in the experience with European foulbrood it was learned by careful observers that strong colonies are essential in successfully combating the disease. Later the value of Italian bees was discovered. West (11), a New York State apiary inspector, in giving what is one of the best early descriptions of European foulbrood, makes some pertinent observations on the disease. He states that when diseased brood is placed above a strong, healthy colony, with a queen excluder between, so that any healthy brood may emerge, the diseased larvæ are cleaned out as this is taking place. The union with a healthy colony and the strength gained by the emergence of so many young bees gives the colony the stimulus to eliminate the disease. He notes, as have many other beekeepers since, that in August, when the buckwheat honey flow begins, the stronger of the diseased colonies are stimulated to clean up.

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[1] Reference is made by number in parenthesis to "Literature cited," p. 28.

Alexander (1) published a method of treatment for European foulbrood, the principle of which, after many varying failures and successes, is now the basis for the present method of treatment most used; that is, requeening with Italian stock. Alexander mentions the need of three factors: First, the necessity of requeening with young yellow Italians, as hybrids of Italian and black bees are prone to contract the disease in the first place and also are more likely to succumb to it; second, particularly emphasized, a period (at least 27 days, according to Alexander) of queenlessness in which to allow the bees properly to clean up the cells and polish them, preparatory for eggs of a new queen; third, a factor which is mentioned only casually but which is equally important with the other two, the direction to unite and strengthen diseased colonies before treating. So little emphasis was placed on this that the majority of beekeepers overlooked it in using Alexander's treatment and therefore condemned the treatment as unsuccessful except in rare cases.

In an editorial (8) in the same issue of the journal in which Mr. Alexander was writing, the question was raised as to why the period of broodlessness caused by winter, which is much longer than 27 days, does not always prevent a recurrence of the disease. Mr. Alexander answered this question by explaining that when the queen stops laying in the fall, the bees do not polish up the cells as they do earlier in the season, and that some of the dried-down material may remain until the next spring. The opinion also is given in this editorial that Italians are more able to resist the disease than hybrids because they do more thorough work in house cleaning and are less inclined to rob.

Phillips (6) makes the statement that "European foulbrood is more destructive during the spring and early summer than at other times, often entirely disappearing during the late summer and early autumn, or during a heavy honey flow," but gives no indication as to how this takes place. The same year Miller (2) published his theory of the relation of the nurse bees to the spread of European foulbrood. He believes that the nurse bees suck up the juices of a freshly diseased larva which has not become offensive, and then transmit the disease when feeding the healthy larvæ. On this supposition he believes that if egg laying ceases for 5 or 6 days ("the period the larvæ remain unsealed in their cells") there will no longer be larvæ in the proper condition for nurse bees to feed upon, nor healthy unsealed larvæ to receive the infection, and the disease will thereby come to an end.

Dr. Miller has been using a 10-day period of queenlessness in his treatment of European foulbrood since his accidental discovery that 10 days were sufficient, but in a later article (3) in enlarging upon his nurse-bee theory he assumes that the larva is fed during a period of 5 days but is not effective as a carrier of infection during the whole time as probably no larvæ are torn open until they are 2 or 3 days old, thus making it possible to shorten the queenless period even more. He admits that not all the dead, partially dried larvæ will be cleaned out, but believes that it is only the fresh yellow ones which are infectious. He also states that nurse bees are not inclined to travel far on the combs, a fact which may explain why the disease may be found confined to one comb for several days before spreading farther. Dr. Miller seems to have overlooked several important factors which will be discussed later.

Quite an extensive piece of investigation was carried on during the summers of 1915 and 1916 by the author at the Massachusetts Agricultural Experiment Station upon the effect of requeening diseased colonies with various strains of Italian bees. At that time the importance of strong colonies with the requeening had not been emphasized so strongly and less attention was paid to that factor. The records show, however, that in a total of 50 colonies observed, covering two seasons, of 10 strong colonies only 2 showed recurrence, while 1 was doubtful; of 20 medium-strength colonies, 10 showed recurrence with 2 doubtful; of 14 weak colonies, 8 showed recurrence. In all these cases the new queen was not introduced until the colony was nearly or entirely clean. In the case of several of the weaker colonies it was necessary to strengthen them before requeening was possible, in order to save the colony. One or two of these, which were united and requeened with Italian stock, were the best colonies the next spring.

Adding some strength to at least part of Miller's theory is a statement in a letter by G. C. Matthews, formerly of this bureau, who wrote in February, 1918, concerning his observations in California in 1914. He found that where the hives stood in rows of pairs the disease continued to spread down each row to corresponding members of each pair. This ceased when he rearranged his apiary so that the rows of hives were at least 10 feet apart, and alternate pairs of hives were turned at right angles. No pair was allowed to remain close to another facing the same way. This prevented the drifting of nurse bees, which he believes to be the method of spreading the disease. Furthermore, he found by introducing one Italian queen into the middle colony of an isolated row of hybrid bees that there was considerable drifting of nurse bees. Seven days after the brood from the Italian queen began to emerge, yellow bees were found on either side in several of the hybrid colonies. Speaking of uniting weak diseased colonies and requeening, Matthews writes:

> After two or three were put together, each stack of brood was given an Italian cell. When young queens commenced to lay there was still disease in many of those hives, but as the queens increased in laying the bees cleaned out an ever-increasing sphere of comb for a brood nest until they had the hives free of disease. But in no case, however long a hive might be queenless, did I see the disease cleaned out before a virgin appeared in the hive. In other words, a virgin had to be present before the bees would commence their job of cleaning up. Therefore, I see little to commend the practice of keeping diseased colonies queenless 21 days.

A new bulletin by Phillips (7) has been issued recently by the Department of Agriculture. The fundamental idea emphasized is that "in keeping European foulbrood under control it is far more important to prevent the disease from getting a foothold in a colony than it is to eradicate the disease afterward." This bulletin, aside from discussing symptoms and methods of treatment, states concisely for the first time the facts observed in apiary practice on which successful treatment is based, and without an understanding of which it is difficult for a beekeeper to use preventive measures with any success.

The analysis of these factors of response in behavior to treatment, as stated by Phillips, has been used to some extent as a foundation for the present work on the behavior of the colony in relation to disease, in an endeavor to substantiate, with data obtained under controlled conditions, these facts that are constantly observed in apiary practice and, if possible, to eliminate confusion in methods of treatment.

PROCEDURE

Shortly after the middle of May, 1918, experiments were started in Ithaca, N. Y., at the Cornell Agricultural College. Through the kindness of Prof. J. G. Needham, head of the department of entomology, and others associated with him, the use of a small, isolated yard of bees and also of laboratory facilities was offered for the purpose of carrying on these investigations. This small apiary had been used previously in fruit-pollination studies and had no record of disease. The yard was admirably located in a naturally well-protected hollow beyond the college fruit orchards, about a mile and a half from the main college apiary or other apiaries, with high ground and woods intervening. The author and the Office of Bee-Culture Investigations are under deep obligations to the Cornell authorities for the assistance so cordially extended.

Being in the buckwheat district, the general locality was well adapted to the work because of the desire for as late a main honey flow as possible in order not to have the influence of a heavy honey flow until other factors had been studied. At Ithaca the main honey flow is generally from buckwheat, coming from the 1st to the middle of August. Rather unfortunately for the best results from the experiments, however, the summer of 1918 was unusual in this section, for the abnormally heavy honey flow from clover necessitated finishing the work earlier than had been planned, owing to the great difficulty of artificially infecting colonies during the heavy honey flow.

There were seven colonies in the original experimental apiary. At first it was intended to work on a larger scale, but the trend of the observations soon led to the plan of working in more detail and on a smaller scale. These colonies were moved some distance apart to prevent drifting and robbing. Some were divided and some were strengthened in an effort to make a series of experiments on colonies of different strengths. The colonies were designated by letter and the combs of each colony by number. From time to time some of these colonies were artificially infected with diseased European foulbrood larvæ from samples sent to the laboratory for diagnosis. Similar colonies were held intact and uninfected for controls. The infection was made by feeding diseased larvæ macerated in sugar solution (about 50 per cent). For the preliminary experiments 10 larvæ were fed in about 250 c. c. of sirup. Later, after the heavy honey flow had begun, it was necessary greatly to increase this dose in order to start the infection. The infected sirup was fed to the bees in sterilized glass petri dishes, placed on top of the frames and protected by an empty comb-honey super placed on the regular hive body with the cover on top.

At the time of inoculation, the condition of each colony was noted as to age, race, condition and appearance of the queen, proportion of nurse bees to old field bees, the number of frames of brood with the amount in each, its age, sealed or unsealed; in other words, the condition of the colony with regard to factors known to be significant in resisting disease. In two colonies the infected sirup was slightly colored with harmless eosin dye to determine where the fresh sirup was placed and its ultimate disposition. At first daily observations were made to determine the earliest appearance of disease, the period of incubation, the symptoms exhibited, and the rate of increase.

By holding up each comb in bright sunlight so that the light shone directly on the larvæ, it was easy to detect the first symptoms of the disease. All the healthy larvæ had the characteristic firm, well-rounded, pearly-white, glistening appearance. The first effect of the disease, besides an abnormal uneasy movement, was a loss of the glistening character and a slight tinge of grayish or creamy discoloration which would not be noticed except in direct sunlight. These larvæ showed only *Bacillus pluton* present when examined microscopically, as will be mentioned later. Soon after these first symptoms, however, the more noticeable symptoms appeared, such as a larva with its back out, the increase of the light grayish yellow color, and, later, the moist, melting appearance.

A statistical record was kept of the number of larvæ showing new disease at each observation, the number previously diseased that had been cleaned out in the interval since the previous observation, and those remaining over in the cells uncleaned for more than one period between observations. At various times observations were made of the behavior and types of bees engaged in cleaning up and the fate of the material removed. Great care was necessary in these observations to disturb the colony as little as possible. On good days it was sometimes possible to remove a comb carefully from the hive and to watch the bees continuing at their work, and even to watch the queen laying eggs. An eight-frame observation hive containing a strong healthy colony was given a diseased comb from time to time and the bees were observed as they worked on it.

One of the difficulties of the work was to find a satisfactory method of recording the desired data for each comb. At first the diseased cells were marked on the comb by a circle of red celloidin around the entrance of the cell. Although this dried rapidly, it proved unsatisfactory, as the bees, in their attempt to remove the foreign material, seemed to remove both diseased and healthy larvæ indiscriminately. Next small pins were used, inserted in the cell above the one showing disease. In this case the bees tore down the surrounding cells and completely removed the pins, many of which were found on the bottom board. Finally a method of plotting the diseased cells in a comb was adopted. An empty frame was laid off in inch squares by means of heavy black thread. This, used as a templet superimposed on a comb, aided in the location of the diseased and cleaned out cells, so that they could be recorded on a correspondingly ruled card (fig. 1). Placing this over the comb, it was easy to locate exactly each cell and to determine how long the diseased material remained, thus aiding in following the course of the disease throughout its various stages. The only difficulty with this method was the tediousness of the observations. Therefore, after the disease had become definitely established, daily observations of each colony were considered unnecessary. Longer periods showed just as well what was happening in the colony. Also, after the disease had developed enough so that it could be definitely predicted whether the colony would recover or gradually be exterminated, observations of behavior under treatment were started, the method and degree of house cleaning being watched after the colony had been dequeened, strengthened, and requeened with good Italian stock. Note was also made of any recurrence of disease and apparent reason therefor. In other words, a complete study was made of the cycle of the disease and of the activities of the bees during its course.

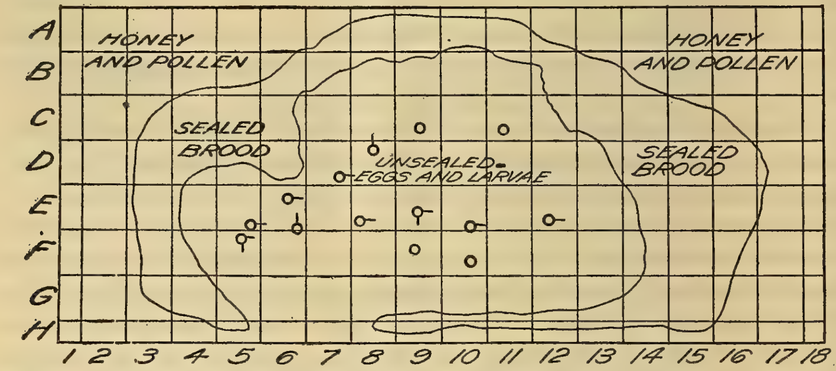

FIG. 1.—Method of plotting the location and history of diseased bee larvæ in the combs. ○ Freshly diseased larvæ. ○– Cells that have been cleaned out. ♀-Cells that have been cleaned out and filled with nectar. ♁ Larvæ remaining in the cells more than one observation period. The area of sealed brood was the amount present at the time of infection of the colony.

OBSERVATIONS

COLONY G

Race.—Hybrid.

Queen.—1917, dark and poor.

Bees.—Workers and drones very dark, almost black, very excitable.

Condition of colony at time of infection.—Brood in four frames, a little less than half sealed, besides two frames of eggs. Bees covering about eight frames, medium strength. Slightly more field bees than nurse bees, because of having divided this colony, old bees returning from the division.

Date of first infection.—May 28, 1918.

Material used.—Ten diseased larvæ from sample No. 5863, macerated in 250 c. c. of a 50 per cent sugar sirup.

First appearance of disease noted.—May 31, 1918, three days after inoculation.

Age of larvæ first attacked.—Three to four days after hatching from the eggs.

Colony G (fig. 2), hybrids, soon succumbed to the infection, the first diseased larva appearing three days after infection, the gross diagnosis being confirmed by the finding of *Bacillus pluton* on microscopic examination. The spread of the disease was rapid, the disease being present in only one comb on the third day and in seven combs on the seventh day. All of this early spread took place in brood unsealed at the time of infection. The first high peak of the disease coming on the nineteenth day was followed by a slight improvement, when for a time the house cleaning exceeded the occurrence of fresh disease. This was probably due to the stimulus of the increasing honey flow. But as soon as the next series of eggs hatched, the disease again gained the upper hand, reaching another higher peak on the thirty-first day, at which time it was deemed necessary to start treatment. It had become evident that the colony was being overrun by the disease. More and more dead larvæ were being allowed to re-

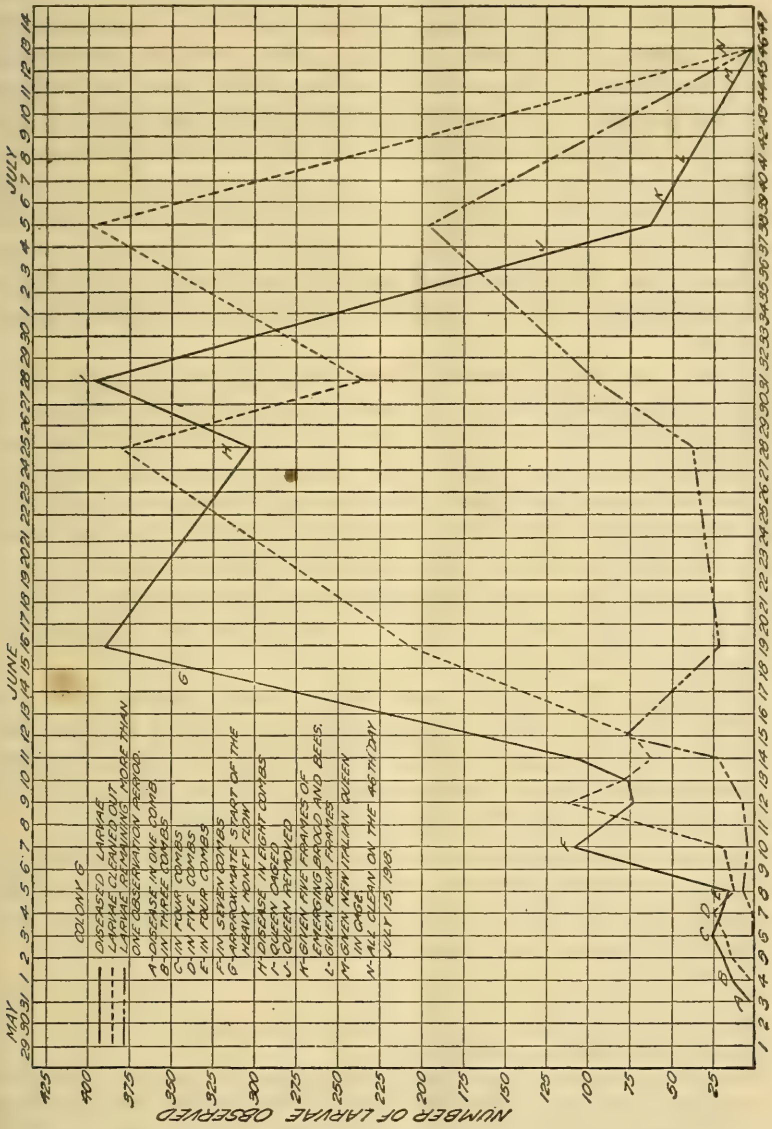

FIG. 2.—The course of European foulbrood in colony G.

main in the cells for several days without being cleaned out. Also more larvæ nearly ready for pupation were being affected. Most of these instead of remaining coiled were inclined to extend on the lower side wall in a brownish gray, slimy mass and exhibited a tendency to be viscid. At this stage of decomposition, when a stick is inserted the mass forms a coarse granular band for a short distance and then breaks so as to form droplike masses, but does not stretch out in a fine thread. These larval masses dried down to rubbery dark brown scales something like American foulbrood scales in appearance, but different in consistency. These scales could be removed quite easily and would bend like a piece of partially granular old rubber. They also lay irregularly placed in the cells, often spirally extended, while American foulbrood scales are uniformly on the lower side wall. The bacteriological explanation for this abnormal characteristic will be discussed later under bacteriological observations.

The predominance of these rubbery masses and scales increased as the disease progressed and the bees seemed to make little attempt to clean them out, even after the queen was caged on the thirty-first day, thus shutting off any increase of fresh larvæ, or even after the queen and all queen cells were removed on the thirty-seventh day. On the thirty-ninth and also on the forty-first day, five and four frames, respectively, of emerging brood and Italian bees were united with this colony, but it was not until a new Italian queen, confined in a cage, had been hung in on the forty-fifth day that a final complete cleaning up was made.

This new queen was not accepted, however, and a young queen was raised from the brood that was added to this colony, so that further observations were ended here although the virgin queen was killed and another Italian queen introduced. This colony was reported healthy, however, about the middle of August.

The hybrid bees seemed to lack ambition to fight the disease. When combs were removed from the colony, the bees never were observed to be working in the cells, and paid little attention to material partially drawn from the cells and crushed.

COLONY F

Race.—Italian, possibly with some slight hybrid blood.

Queen.—1917, fairly good condition.

Bees.—Workers, good color, fairly quiet, drones inclined to be darker.

Condition of colony at time of infection.—Brood in three frames, a little more than one-third sealed. Bees covering about six frames. Building up well. Proportion of field bees to nurse bees about equal.

Date of first infection.—May 31, 1918.

Material used.—Ten diseased larvæ from sample No. 5874, macerated in 250 c. c. of a 50 per cent sugar sirup.

First appearance of disease noted.—June 4, 1918, four days after infection.

Age of larvæ first attacked.—Four days after hatching from the egg.

Colony F (fig. 3), which was the next one to be infected, although not as strong as colony G, was of Italian stock and did not show the appearance of disease until one day later. On the fourth day one cell appeared in each of two combs. It was not until the twenty-fifth day that the disease had spread to seven combs, the total number of diseased larvæ being, as a whole, less than in the hybrid colony. There was not brood in all seven combs at the time of infection, but the brood increased faster than the disease spread. After the twenty-fourth day a permanent improvement began to be manifest.

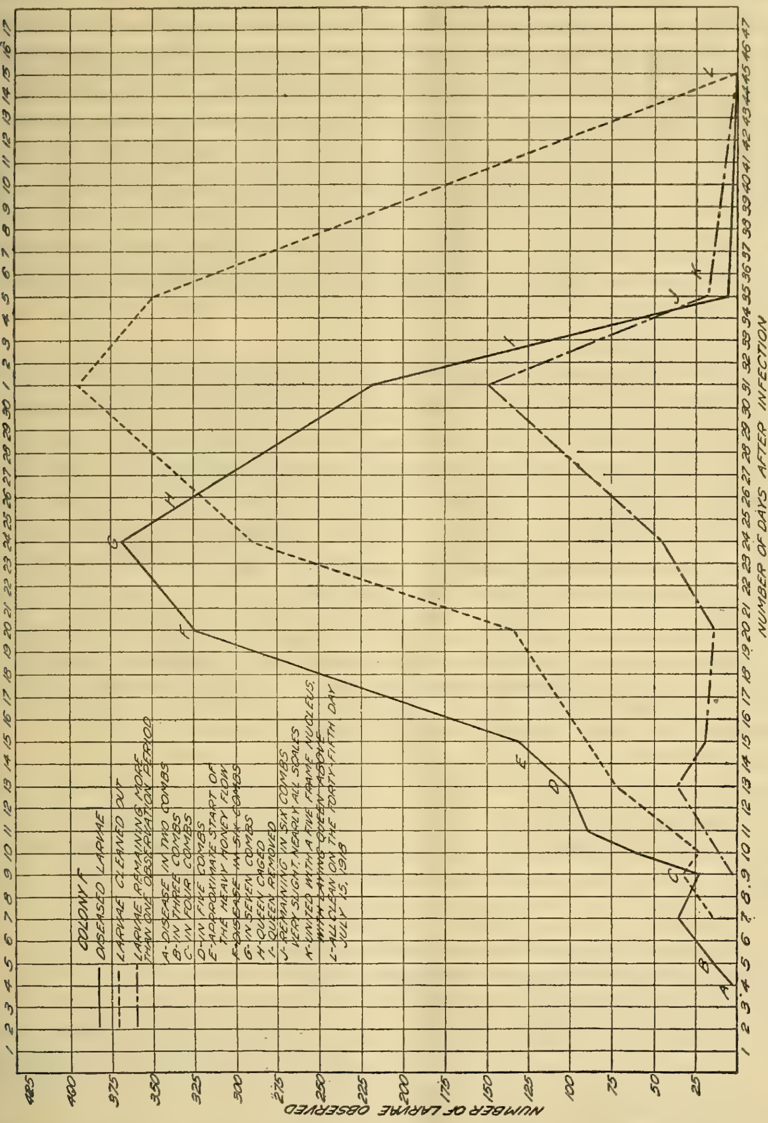

FIG. 3.—The course of European foulbrood in colony F.

This improvement continued after the queen was caged and became more marked after she was removed from the colony.

These bees were better house cleaners as well; the appearance of larvæ remaining over more than one observation period did not become evident until after the ninth day, compared with the sixth day in colony G. At no time were there as many of the larvæ nearly ready to pupate that were gummy or rubbery. Even though this colony was on the average weaker than colony G all the time, it handled the disease much better. It was 14 days before colony G had cleaned up to such an extent that it was deemed safe to introduce a new queen, while in colony F, with the Italian bees, the combs were so nearly cleaned of everything but a few old scales that a five-frame nucleus with a new Italian laying queen was united with this colony after a 10-day queenless period and in 9 days more everything was absolutely clean and the queen was laying in the combs that had had disease in them.

When an observation was made nine days after the new queen's eggs were first noted, it was found that there was a slight recurrence of disease in three of the combs. But, unfortunately, at the same time, queen cells and no eggs were found, denoting that for some reason this queen had not been accepted. Therefore the queen cells were all removed and a new queen was introduced. Although the author's observations ended of necessity soon thereafter, it was reported to him that this colony was doing nicely later in August and was perfectly healthy. If the first new queen had not disappeared, it is quite probable that as soon as a sufficient number of her bees had emerged they would have cleaned up the recurring disease in the same manner as was done in colony J, which will be mentioned later.

Several times in this colony, during the cleaning-up process, bees were watched in the act of sucking up juices of diseased larvæ that had been partially removed from the cells with the aid of forceps.

COLONY H

Race.—Hybrid, a division of Colony G, hybrid.

Queen.—1918. Of their own raising. Poor.

Bees.—Dark hybrids, almost black, excitable.

Condition of colony at time of infection.—Brood in three frames, a few eggs in one, only one small patch sealed, the remainder from eggs up to 4-day larvæ. Bees covering about five frames. Fairly good proportion of nurse bees.

Date of first infection.—July 1, 1918; second infection, July 8, 1918.

Material used.—20 old, dried, rubbery, diseased scales from sample No. 5898, macerated in 250 c. c. of a 50 per cent sugar sirup, colored with eosin.

First appearance of disease noted.—July 5, doubtful. Positive July 8, 7 days after infection.

Age of larvæ first attacked.—Four days after hatching from the egg.

Colony H (fig. 4) was treated as a double experiment. The infection of this colony was not started until after the honey flow had come on quite heavily. Also, instead of freshly diseased larvæ, old brown rubbery scales were used that showed *Bacillus pluton* present microscopically, but were heavily overgrown by *Bacillus alvei.* It was desired to learn whether these scales were still infectious, so that nurse bees working on them, cleaning them out, might get infective material on their feet and mouth parts which could be carried to healthy larvæ. This was noted later in the observation hive, where, under the magnifying glass, bees were seen trying to remove some of these rubbery scales, first moistening them with their tongues and then pulling at them with the mandibles and front feet.

This colony, which was marked hybrid and weak, was slow in developing the disease, partly because of the diluting effect of the heavy honey flow and probably partly because there was a smaller number of infectious organisms present in the scales than in fresh larvæ. This is explained by the fact that the secondary putrefactive invading organisms would tend to kill off the primary organism, because of the accumulation of the products of the putrefactive action.

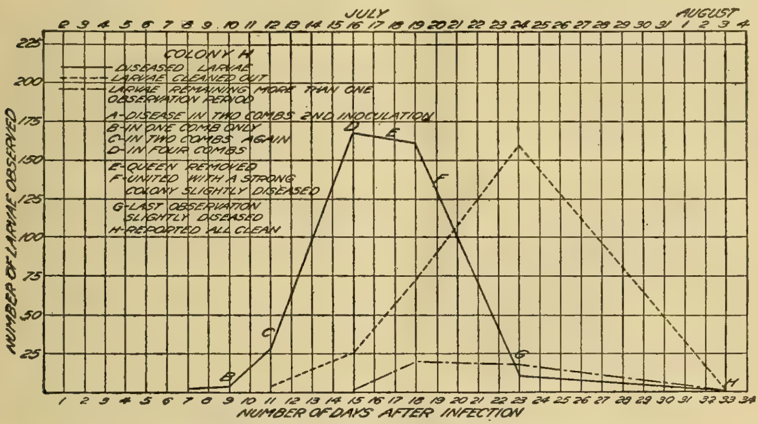

FIG. 4.—The course of European foulbrood in colony H.

On the seventh day before the disease was first noted, a second infection of scales macerated in sugar sirup was given this colony to counteract the effect of these retarding factors. However, later on the seventh day, diseased larvæ were found, and from then on the disease started to spread and increase irrespective of the heavy honey flow, exhibiting all the symptoms and tendencies shown in colony G, of which this colony was a division before infection.

On the seventeenth day it was necessary to remove the queen and start treatment, but what was taking place was evident. This removal of the queen did not seem to have a very marked effect on the house cleaning until the colony was united with colony I, a slightly diseased Italian colony. They then began cleaning the H combs, and the combined colony was reported clean in August.

COLONY A

Race.—Italian with some possible slight hybrid blood.

Queen.—1918. Of their own raising.

Bees.—Workers, good color; fairly quiet. Drones, some slightly darker than pure Italians.

Condition of colony at time of infection.—Brood in seven frames about half sealed. Bees covering about nine frames with a good proportion of young nurse bees. Colony strong and building up.

Date of first infection.—July 2, 1918. Second infection, July 6, 1918.

Material used.—First, 20 diseased larvæ from sample No. 5937 macerated in 250 c. c. of a 50 per cent sirup, colored with eosin, abnormally heavy infection; second infection, 20 diseased larvæ from sample No. 5953 in 250 c. c. of uncolored sirup.

First appearance of disease noted.—July 8, 1918, in drone brood, six days after infection.

Age of larvæ first attacked.—Four days after hatching from the egg.

Colony A (fig. 5) was a fairly strong colony of Italians. Like colony H, it was infected after the heavy honey flow had started and was given twice the amount of infective material colonies F and G received. Nothing having appeared on the fourth day, a second infection of the same amount was given. On the sixth day 6 diseased larvæ were seen in three combs. This colony, however, was so strong that the disease obtained very little foothold, and from the fourteenth day began to decline, or at least failed to make further gains. As a side experiment in this colony a comb of eggs laid by an Italian queen was placed in between two combs showing disease. If there is anything in the belief that Italian stock is more resistant to disease, the larvæ in this comb should not have developed the disease, or at least not so soon. However, on the sixth day one or two larvæ showed disease, increasing slightly in numbers for a few days until the observations were of necessity stopped. It was intended to perform this experiment with several variations, such as placing eggs laid by an Italian queen in a diseased hybrid colony and placing eggs from

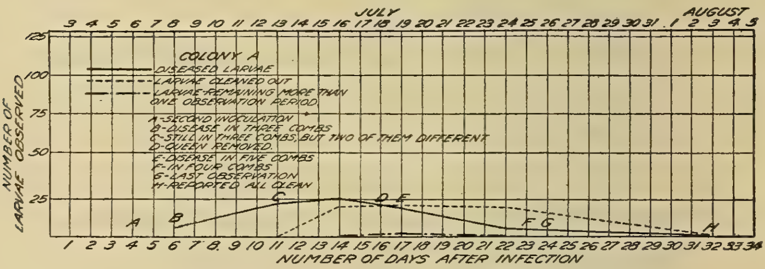

FIG. 5.—The course of European foulbrood in colony A.

a hybrid queen in a diseased Italian colony, but the presence of the heavy honey flow made it impracticable to carry the matter further.

This colony A cleaned up readily after removal of the queen and was reported all healthy in August. Although a new queen was given to them it is probable that a period of queenlessness and the returning of the same queen would have answered just as well.

COLONY I

Race.—Italian.

Queen.—1917, fairly good condition.

Condition of colony at time of infection.—Seven frames of emerging brood well covered with young bees. A strong 8-frame colony.

Date of first infection.—July 10, 1918.

Material used.—Thirty diseased larvæ from sample No. 5959, macerated in 250 c. c. of a 50 per cent sugar sirup. This was abnormally heavy infection of diseased material.

First appearance of disease noted.—July 15, 1918, five days after infection.

Age of larvæ first attacked.—Four days after hatching from the egg.

This colony was infected during the heavy honey flow, but although given a heavy infection it had sufficient strength, aided by the heavy honey flow, to prevent the disease from spreading. On July 15 there were a few diseased larvæ in two combs. On July 24, 14 days after inoculation, there were only a few diseased larvæ in three combs. This was after the queen had been removed on July 18 and the colony had been united with colony H on the 20th.

An interesting observation was that under the magnifying glass the methods of the nurse bees in sucking the juices from dead diseased larvæ and the pulling of the skins out to carry them away could be noted. No bee worked very long at a time on one larva. One after another worked until all was completed.

SUMMARY OF PREVIOUS EXPERIMENTS

Table I gives a partial summary of the data thus far described.

TABLE I.—*Showing the first appearance of disease noted after infection. Also the number of combs showing infection and the spread of the infection from comb to comb in the various colonies under observation*

Colony.	Date infected.	Days after infection.																											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
		Number of combs.																											
G[1]	1918 May 28	..	..	1	3	..	4	5	4	..	7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8
F[1]	May 31	..	..	..	2	3	..	..	..	4	...	...	...	5	...	...	...	...	...	...	6	...	...	...	7	...	...	...	...
H[2]	July 1 July 8		..	..	..	..	..	2	..	1	...	2	...	...	...	4	...	...	...	...	...	...	...	...	...	...	...	...	...
A[2]	July 2 July 6		..	..	..	..	3	...	...	...	...	...	...	...	...	...	...	5	...	...	...	...	...	4	...	...	...	...	...
I[2]	July 10	..	..	..	..	2	..	..	..	..	...	...	...	...	3	(Different from first two.)									...	...	...	...	...

[1] Experiments started before the beginning of the heavy honey flow.
[2] Experiments started after the beginning of the heavy honey flow.

In the first group, colonies G and F, it is quite apparent that the Italian bees, colony F, made the better showing, even though the hybrids were the stronger colony in the beginning. As may be seen from a comparison of the two plots in figures 2 and 3, in colony G wherever there was a lag in the house cleaning there was marked increase in the number of larvæ remaining over more than one observation period, and these increased until strengthening treatment was started. On the other hand, in colony F these were removed almost entirely by the time the strengthening treatment was started. The Italians did not allow the disease to appear as soon or to spread as rapidly, cleaned house better, left fewer larvæ to dry down to the brownish rubbery scales, and responded to the increased honey flow and treatment much more readily.

In the second group, colonies H, A, and I, the Italian colonies A and I again made the best showing. With the added diluting effect of the honey flow, they allowed the disease to gain no foothold whatever, while the hybrids, though aided by the honey flow, soon succumbed and allowed the disease to gain on them. It is evident that the Italian bees are much more vigorous house cleaners. In several instances, toward the end of the egg laying of the old queen, and well along in the progress of the disease, cells were noted on these diagrams which had previously contained diseased larvæ, but which had been cleaned out, and then in which disease had reappeared after other eggs had been laid and hatched in them. They were cells in which fresh nectar had not been placed between the two series of larvæ.

It was also noted that as the honey flow increased and as the brood became more scattered from the effects of the disease, more and more fresh nectar was placed in the brood nest in cells from which dead larvæ had been removed. Most of this nectar, however, was moved up later, particularly after the bees began preparing the brood nest for a new queen in the process of treatment. That the advent of a heavy honey flow was effective in controlling the disease is evident, particularly in the length of time between the infection and the first appearance of disease. The data, however, show little difference in the resistance to infection, or so-called immunity, being slightly in favor of the Italians, if there is any difference at all.

Disregarding the effect of the honey flow, the period of incubation of the disease is apparently between 3 and 4 days. However, it was noted that after *Bacillus pluton* was first observed it was anywhere from 24 to 48 hours before many characteristically diseased larvæ were observed. Therefore, the actual period of incubation is probably from 24 to 48 hours.

SUPPLEMENTARY OBSERVATIONS

STUDY OF NATURALLY INFECTED COLONIES

As a supplementary study to the preceding artificial infection experiments, some observations were made upon the behavior of naturally infected colonies undergoing treatment. Through the kindness of W. L. Bean, of McGraw, N. Y., it was possible to make a series of such observations. In his apiary of about 30 colonies, all hybrids, the majority were diseased when observed June 8, 1918. Soon thereafter Mr. Bean kindly loaned two of these diseased colonies to be carried to Ithaca for closer observation. Mr. Bean at once started treating his bees, requeening with Italian stock by the method of introducing a queen cell almost ready to emerge. Apparently, this method was successful, for in the latter part of July Mr. Bean reported all treated colonies healthy and some 800 pounds of surplus honey.

COLONY J

Race.—Hybrid.

Queen.—Queenless at time of arrival at Ithaca. Was poor hybrid of own raising, probably reared while disease was present in the colony.

Strength in spring.—Weak.

Strength at time of treatment.—Scattered brood in eight frames. Weak in bees, particularly in nurse bees.

Approximate date of disease first noted.—May 31, 1918.

Date of start of treatment observations.—June 16, 1918.

This colony made no effort to clean up, even though they had lost their queen shortly before being brought to Ithaca. On the 18th of June six frames of Italian bees and emerging brood were placed on top of it. At once house cleaning started, a reduction of 50 per cent being noted in the fresh, moist, melting larvæ within 24 hours. In this colony it was interesting to watch the bees doing the house cleaning, particularly when diseased larvæ in various stages of decomposition were partially withdrawn from the cell with a pair of forceps. With the aid of a powerful hand magnifying glass it was easy to watch them suck up the juices of the dead larvæ, even those which had decomposed to the extent of being a coffee brown in color and viscid in consistency. No bee would work long on a larva but would back off and wipe her tongue thoroughly with her front feet. It is conceivable that this might contaminate her, making possible carriage of the infection to the next larva fed, even though the juices of the diseased larva were not actually fed to the healthy one. The majority of bees engaged in this work were the Italians. From these and other observations of a similar nature there is no doubt that the contamination of the mouth parts is the primary method of spreading the disease inside the colony.

On June 25 an Italian queen was introduced in a cage with candy even though a few scales were still present. This was fully 10 days after the colony had lost its queen, if not a little longer. On June 27 the queen was out and laying in one comb. Eight days later, on July 5, a recurrence of disease was noted, one larva being discolored and sunken, showing *Bacillus pluton* on microscopic examination. From that time on, for about 20 days after the first eggs of this queen were noted, one or two new diseased larvæ appeared at each observation, the number decreasing, however, until about the twenty-sixth day when they had all disappeared. As the new young Italian bees increased, the disease decreased, until a point was reached where they were in the predominance and had eliminated the disease by their activity. This was also observed in colony F.

COLONY K

Race.—Hybrid.

Queen.—1917. Dark hybrid of their own raising, probably from diseased stock.

Strength in spring.—Weak.

Strength at time of treatment.—Eight frames of scattered brood and hardly enough bees to cover them.

Approximate date of disease first noted.—May 31, 1918.

Date of start of treatment observations.—June 20, 1918, at which time the queen was removed.

Colony K, when it was brought to Ithaca, was so weak that it would soon have died. The bees made no attempt to clean out larvæ that had been partially pulled out of the cells with forceps and crushed. On June 26, six days later, they were still showing freshly diseased, moist, melting larvæ from eggs laid by the old queen, just before removal. At this time five frames of emerging brood and Italian bees were given this colony. On the 27th a new Italian queen was hung in with the cage closed. The presence of the new queen, however, seemed to give added impetus to the house cleaning so that by July 1, 11 days after removal of the queen, they were practically cleaned up and the cage was opened with candy in the opening. Further observations on this colony were ended because they refused to accept this queen. By the time another queen finally was accepted and was laying on July 18, it was too late, as the season's work was closed by the 23d.

BEHAVIOR OF BEES IN CLEANING CONTAMINATED CELLS

On June 6, 1918, a sample was received for diagnosis (No. 5898), consisting of an entire brood comb, containing quite an area of capped honey. About one-half of each side of the comb contained a large number of dead and diseased European foulbrood larvæ, in stages varying from the yellowish, moist, melting larvæ to dried rubbery scales of which there was quite a large proportion. This was the same sample from which infectious dried scales were used to infect colony H. After this comb had remained in the laboratory, wrapped in paper for about 3 weeks, it was placed in the strong colony in the observation hive. The frame was first placed in the middle of the hive for about an hour and was then removed to the outside, where the work of the bees on it could be watched. A large number of what appeared to be young nurse bees were already hard at work on the dried diseased material. The bees, working on the dried gummy masses, would wet the mass with their tongues for a while and then tear at them with their mandibles, at times removing pieces large enough to be seen from the outside. Often these small pieces were apparently dropped to the bottom board. No one bee worked long at one place. Those bees working particularly on the fresh, moist material, when leaving, would carefully wipe their tongues with their front feet, thereby transferring some of the infection to them. Other bees were at work carrying away the larger, more easily removable dead masses. The entrance also was watched to see if any of this material was carried out. Several bees were observed carrying out portions of dead larvæ or pupæ. One bee carried a piece about 2 yards before dropping it. Others dropped what they were carrying soon after leaving the entrance, but on examining the surface of the ground about the entrance, very little material could be distinguished, so that apparently most of the material removed must have been carried some little distance before being dropped. After about an hour's work it was apparent that considerable progress had been made. This comb was removed before it was entirely cleaned and later placed in another healthy colony for observation. It was quickly cleaned up and quite a bit of nectar placed in it and, eventually, several square inches of brood. Observations, however, had to be stopped before any appearance of recurrence was noted. This same observation hive was given one or two other diseased combs to clean, but with the repeated probable infection from these sources the colony was so strong that no disease was noted in it during the entire season of observations.

POSSIBLE INFECTION THROUGH QUEEN

Colony M was a small nucleus made to receive the old queen from diseased colony K from McGraw, N. Y. The queen was introduced on June 20, 1918. For a while she laid fairly well, it being necessary to add one or two more combs. But later her brood became more and more scattered. Finally, on July 8, there was observed one dead larva, which looked suspicious, but which, on microscopic examination, proved to be negative. On July 10, however, one definite cell appeared and several other slightly yellowish, abnormally colored larvæ. This dead larva contained *Bacillus pluton.* From then on until this queen was killed and the colony united with another diseased colony, more discolored larvæ appeared, showing definitely the development of the disease. As far as could be seen the only source of infection was the queen which had come from a diseased colony.

This occurrence had been observed previously by the author while employed at the Massachusetts Agricultural Experiment Station. During the summer of 1916 eight queens taken from diseased European foulbrood colonies were introduced into isolated, healthy nucleus colonies. Of these eight nuclei three developed European foulbrood, two were doubtful, and three remained healthy. Several such instances have been mentioned in the literature of beekeeping.

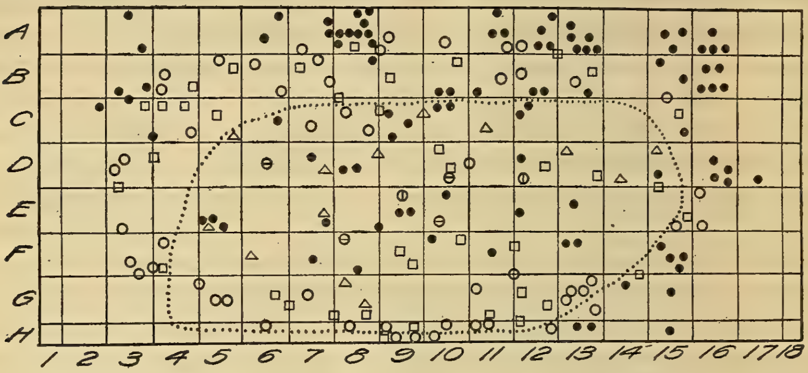

Fig. 6.—Distribution of cells containing infected sugar sirup and subsequent spread of the disease in a comb taken from colony H. . . . . Area covered by brood at time of infection, mostly unsealed. ● Location of cells containing infected colored sugar sirup on July 3, 1918. ⦶ First positive diseased larvæ noted, 2 on July 8. ⊖ Number of new diseased larvæ (4) on July 10. △ Number of diseased larvæ (13) on July 12. □ Number of diseased larvæ (39) on July 16. ○ Number of diseased larvæ (52) on July 19.

DISTRIBUTION OF INTRODUCED INFECTED MATERIAL

An interesting experiment was carried out with sugar sirup, colored by a small amount of a harmless anilin dye, eosin, used as an indicator, which gave to the sirup a bright red color. The object of this experiment was to determine where the sirup, or, more important, where fresh nectar is first placed in the hive and combs. On May 27 two colonies were fed this colored sirup from above some time before the heavy honey flow from clover started. The results were striking, for in nearly every case the colored sirup was easily discernible in the cells and the greatest part of the sirup was located in quite a definite area. These colored cells were either scattered among the cells containing the larvæ or were placed in a ring of cells adjacent to the brood area toward the top of the comb, little being placed with the solid stores (fig. 6). Furthermore, for nearly 36 hours after the feeding practically all the young nurse bees showed a marked pinkish discoloration of the anterior end of their abdomens, denoting the distention of the honey stomachs by the retention of the colored sirup therein. About half the bees in the hives were discolored in this manner. After a day or so, however, this begin to disappear. Also the number of cells showing the pink discoloration began to disappear. Evidently the sirup had been moved up, worked over, and mixed with other nectar or consumed.

Later, some time after the heavy honey flow had started, shortly after July 1, two more colonies were fed colored sirup, this time infected with diseased larvæ macerated therein.

In these cases the discolored abdomens were noted about as before, but the colored cells were less numerous and the color less striking. The location of the colored cells was similar to that in the former experiment; that is, mainly in the brood area or just contiguous to it and mostly above. The outside combs, containing considerable honey, showed scarcely any of the colored cells. This time these colored cells disappeared sooner, showing that the infected material must have been much diluted quite soon after being taken up from the feeding dishes.

Figure 6 shows the method of plotting the location of diseased larvæ in the combs and also the location of the cells containing the colored sugar sirup. As will be noted, a fairly large proportion of these cells are located within the area of brood at the time of feeding. It is interesting to note the tendency of diseased brood to form concentric circles, showing the two series of larvæ occurring between the dates noted. The spreading was from two cells at first to quite a large number at the last observation shown.

AGE AT WHICH LARVÆ ARE INFECTED

In previous observations it was constantly noted that the larvæ affected by European foulbrood were regularly at least 4 days old, the age at which the coiled larvæ completely fill the bottom of the cells. Occasionally a slightly younger and smaller larva would become diseased, but this was not the common occurrence. Furthermore, in the cases where the colored sirup was fed the bees, within 24 to 36 hours quite a number of larvæ averaging 4 days old could be seen discolored from having been fed this sirup, while it was noticeable that the younger larvæ under 3 days old never showed the discoloration. These colored larvæ were examined in a smear under a microscope, but the infecting organisms, being comparatively few in number, had not increased sufficiently at that time to be apparent.

The question now arises as to the age at which the larvæ first are fed nectar or infected material. There has been much controversy over the subject of composition and source of the larval food, but as yet no conclusive scientific evidence has been presented. Irrespective of the question whether the food at various stages originates from glands or is regurgitated, it is apparent from these observations that there must be a difference between the food which larvæ younger than approximately 3 days old receive and that fed to older ones. Otherwise the younger larvæ would also show the pink coloration. Von Planta (9) by chemical analyses, of questionable exactness, however, makes a division in the feeding of the larvæ at the age of 4 days, at which time the high protein and low sugar content change to lower protein and higher sugar content. These analyses would tend to coincide with the above observations, only it is probable that the change begins earlier.

Additional data upon this subject are recorded in Tables II and III, although the observations were primarily for another purpose. In order to obtain further information relating to a possible difference in resistance to disease between Italian and hybrid bees, a careful record was made of the time when eggs were first noted in empty combs after the infection of the colony and when larvæ first showed disease thereafter. In the case of comb Special No. 2, the eggs were laid by an Italian queen in a healthy colony and then placed in a diseased colony. Colonies F, A, and I were of Italian stock while colonies G, H, and J were hybrid. In the recurrence of disease all were given new Italian queens. As has been mentioned before, as soon as the bees of the new Italian queens emerged in sufficient numbers the disease disappeared.

TABLE II

THE FIRST APPEARANCE OF DISEASE IN COMBS IN WHICH EGGS WERE LAID AFTER THE COLONY WAS INFECTED

Colony and comb No.	Number of days after eggs were first noted in comb.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
G 4										×				
G 6							×							
G 7						×								
G 8							×							
F 3							×							
F 4								×						
F 7						×								
H 3									×					
H 5									×					
A 2											×			
A 4											×			
A 5						×								
A 7								×						
A 8											×			
Spec. 2						×								
I 3									×					

RECURRENCE OF DISEASE AFTER EGGS OF A NEW QUEEN WERE FIRST NOTED IN THE COMBS

Colony and comb No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
J 2														×
J 3														×
J 4							×							
J 5								×						
J 6a							×							
J 6b											×			
J 7										×				
J 8							×							
F 3									×					
F 4									×					
F 7									×					

Table III.—*Average time, under various conditions, in which disease becomes apparent in a colony after infection with European foulbrood. (Averages taken from Table II)*

	Before the heavy honey flow.
	Days.
Colony G, hybrid	7½
Colony F, Italian	7
Average of these two	7¼
	During the heavy honey flow.
	Days.
Colony H, hybrid	9
Colony A, Italian	8⅚
Colony I, Italian	9
Average of these three	$8\frac{17}{18}$
	Recurrence of disease, after treatment, during honey flow.
	Days.
Colony J, hybrid originally	9¾
Colony F, Italian originally	9
Average of these two	9⅜

The data shown, particularly in Table III, tend to disprove the theory that Italian bees have a natural immunity or resistance. If a larger number of observations could have been made, the variation would have appeared less. The effect of the honey flow is evident, however.

When it is a question of the age at which the larvæ are fed material that contains infection, these figures are significant. In the life history of the bee, 3 days are spent in the egg and from 5 to 6 days as larva before capping, making a period of 9 days in all. After 3 days in the egg and after having been fed predigested food for 3 days, with the additional 24 to 48 hour period of incubation, as was observed earlier in this paper, the larva ought to show disease from the fourth to the fifth day after hatching, or the seventh to eighth day of its existence, if Von Planta's assumption is correct. From actual observation this was found to be true and from observation of the averages in Table III it is seen that the first appearance of disease occurs between the seventh and ninth days, varying with the conditions of the honey flow.

Referring to Dr. Miller's theories, it is hard to believe that there is not plenty of highly infectious material left in the colony after a 5 or 6 day period of queenlessness. Aside from actual observations of moist, yellow, melting larvæ present more than 6 days after the queen has been removed, the juices of which the workers sucked up with avidity, the final eggs laid will be just at the stage where the disease first appears; that is, 3 to 4 days after hatching, at the end of a 6-day period. Furthermore, even though the nurse bees do not feed to healthy larvæ the material that is taken up in cleaning out the cells in varying stages of decomposition, infection, even from scales, may be carried on the feet, mouth parts, and tongue, particularly, as was definitely shown with colony H, since these scales are infectious. The period of queenlessness and the consequent house cleaning are absolutely dependent on the strength of the colony. A strong colony cleans up rapidly, particularly after the introduction of the new queen in a cage plugged with candy. A weak colony, on the other hand, has not sufficient bees to clean even after complete introduction of a queen, and the disease soon appears again. Under average conditions, therefore, it would appear unsafe to allow less than a 10-day period of queenlessness in treatment of European foulbrood.

MICROSCOPICAL BACTERIOLOGICAL OBSERVATIONS

A large number of microscopic examinations were made of larvæ under various conditions for the positive presence of the characteristic groups of *Bacillus pluton.* These examinations were made mainly as a check on the gross observations of the first appearance of the disease. Cover glass smears were made of crushed larvæ, stained with carbol fuchsin and mounted in Canada balsam. These examinations were made at regular intervals after the colonies were infected, larvæ of all ages being examined.

It was found in the smears of those larvæ showing the first slightly abnormal symptoms that *Bacillus pluton* was the only organism present. This substantiates White's (12) observations that before the disease could be detected by gross examination, by a histological study of sections of larvæ during the period of incubation it was demonstrated that "in the production of the disease *Bacillus pluton* was the first invader of the healthy larvæ."

As the disease advanced in the various colonies, observations were made of larvæ in various stages of decomposition. The bacterial content was found to vary with the change of appearance of the larvæ during decomposition. The presence of these secondary invaders easily explains the atypical appearance of certain types of European foulbrood that heretofore have been very confusing to the beekeeper.

For a short time after the death of the larva, the color remains a moist, creamy-grayish yellow. This is during the period when *Bacillus pluton* and such occasional secondary invaders as *Streptococcus apis* or *Bacterium eurydice* and other organisms, which do not form spores, are predominant as described by White (12) and McCray (4). Soon the putrefactive spore-forming organisms increase in number, *Bacillus alvei*[1] being the one most commonly found. This is seen particularly in the case of the more mature larvæ, which when dying extend more or less irregularly in the cells, becoming the grayish brown slimy masses which develop into the dark brown granular rubbery scales. This fact has been observed for a long time in the many samples which have been received for diagnosis. A partial description of these scales and of the presence of *Bacillus alvei* in them is given by McCray and White (5), but the experimental observations described in this paper added to diagnostic observations show that this condition is generally much more pronounced and common than described by these writers from laboratory observations. The rapid increase and peculiar process of decomposition of *Bacillus alvei*, after the death of the larva, often to the exclusion of all other organisms, accounts for this abnormal appearance. In the case of American foulbrood, almost never is any other organism found associated with the disease but *Bacillus larvae*, the cause of the disease. This accounts for the constancy of the symptoms as compared with the variation of symptoms in European foulbrood where there may be several secondary invaders.

Furthermore, in making the smears of the diseased larvæ upon cover glasses, the peculiar whitish saclike extrusion of the larval intestines was often noticed on crushing the larvæ preparatory to smearing, which White (10) describes as a gross diagnostic character. When this sac was removed and smeared separately, it was always found to be heavily loaded with *Bacillus pluton*. Therefore it is safe to assume that the intestinal tract is the primary focus of infection, while the secondary putrefaction takes place mostly in the body tissues of the dead larva.

Coincident with the microscopic examination of larvæ, several examinations were made of the contents of the ventriculus, rectum, and in a few cases of the honey stomach and mouth parts of bees. These bees were presumably nurse bees taken from diseased combs, some in the very act of sucking up the juices of dead diseased larvæ. Although insufficient observations were made to give conclusive evidence, some interesting information was obtained.

As may be seen from Table IV, the number of cases where *Bacillus pluton* or other organisms associated with infectious material were found in the intestinal contents is not very large. However, of more importance probably, *Bacillus pluton* was found in a smear made from the mouth parts of a nurse bee and also in the contents of the honey stomach of another. If these observations had been carried out systematically, instead of only casually, it is expected that much more positive data might have been obtained along these lines, owing to what is known already of the habits of house-cleaning bees working on diseased material.

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[1] *Bacillus alvei* originally was supposed to be the primary cause of European foulbrood, but has been proved by White and others to be only a common secondary invader. *Bacillus alvei* has purely putrefactive functions. From its cultural and biochemical characteristics, *Bacillus alvei* apparently belongs to the common *Bacillus subtilis* (hay bacillus) group of spore-forming organisms, all having mainly putrefactive functions.

TABLE IV.—*The results of the microscopic bacterial examination of the contents of the intestinal tracts of nurse bees taken from diseased colonies*

Microscopic findings.	G.	F.	H.	A.	I.	J.	K.	Total.
Positive *Bacillus pluton*..............	1	2	2	....	....	....	4	9
Negative *Bacillus pluton*..............	11	24	18	17	12	6	9	97
Bacillus alvei or doubtful *Bacillus pluton*..............................	....	3	1	....	....	7	....	11

SUMMARY AND CONCLUSIONS

In arriving at the following conclusions an effort has been made to state them in a manner which will indicate the substantiation of previous observations made both in the laboratory and in the apiary. It may be noted that many of these conclusions are similar to some of the statements made in Farmers' Bulletin 975 in the summary of facts which apiary practice has brought out.

1. European foulbrood is an infectious disease. *Bacillus pluton* was found to be the primary invader, appearing in the intestinal tract of larvæ before death, contemporary with the first slightly apparent symptoms.

2. The variation in the appearance of the diseased larvæ after death is due to the presence or absence of secondary invaders.

3. The period of incubation for European foulbrood was found to be from 36 to 48 hours, although the gross symptoms usually do not become apparent in less than 3 or 4 days, varying with conditions of honey flow and strength of colony.

4. It has been noted in apiary practice that the first brood of the year usually escapes with little loss. During the first 5 to 7 days the spread of the disease in the colony after infection is slow, after which the increase is rapid under favorable conditions. The critical time, therefore, to detect the disease and start treatment is early in its course, thus making conditions unfavorable.

5. The evidence tends to confirm the theory that one of the ways the disease is spread in the colony is by the house-cleaning bees, and from colony to colony by their drifting. It is quite probable that the infective organisms are carried on the mouth parts and pedal appendages. The question of infection from intestinal contents or from

the source of larval food at various stages needs further substantiation.

6. Irrespective of strength of colony, the Italian bees were found to resist infection much better than hybrids and showed more ability to overcome the disease.

7. This apparent resistance of the Italian bees was observed to be largely due to the more vigorous house-cleaning characteristics rather than to a natural resistance or immunity to the disease. There was very little difference in the apparent period of incubation between the Italian and hybrid colonies, possibly a slight difference in favor of the Italians. Furthermore, it was noted that often there may be a slight recurrence of disease in the brood of the new Italian queen until a sufficient number of her bees have emerged to eliminate the infection by house cleaning. Apparently, infection is not always entirely removed by a period of queenlessness.

8. As a rule, requeening is necessary in the treatment of European foulbrood, except possibly in the strongest Italian colonies, which show only slight infection. Where a considerable quantity of disease is present, sufficient to require treatment, it was found unsafe to use a period of less than 10 days' queenlessness, due to the infectious condition of the diseased material remaining and the accompanying behavior of the colony.

9. The stronger the colony in Italian bees, the more rapid was the recovery.

10. A heavy honey flow tends to prevent infection from gaining a foothold. It also tends to eliminate the disease if present before the start of the heavy honey flow. This was found to be due to the effect of dilution on the infection because of the influx and direct feeding of the fresh nectar to the larvæ.

11. European foulbrood is a disease of weak colonies. It was found to be difficult effectually to infect any but the very weak colonies during the heavy honey flow. Therefore, colonies kept strong up to the time of the honey flow run very little danger of contracting European foulbrood. This and others of the facts observed are in exact harmony with facts already observed in apiary practice.

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[1] "Black brood" is an old name for European foulbrood.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 805

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER December 15, 1919

TWO LEAFHOPPERS INJURIOUS TO APPLE NURSERY STOCK.

By A. J. ACKERMAN,
Scientific Assistant, Deciduous Fruit Insect Investigations.

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INTRODUCTION.

Serious injury to apple nursery stock due to the attack of leafhoppers attracted the writer's attention while engaged in the investigation of nursery fruit insects at West Chester, Pa. An examination of the injury showed the presence of two species of leafhoppers, the common apple leafhopper[1] and the rose leafhopper.[2] Further study proved that each species produced a distinct type of injury, that caused by the apple leafhopper being by far the more serious. The conflicting nature of the entomological literature regarding the character of injury caused by these two species and their habits led the writer, under the direction of Dr. A. L. Quaintance, of the Bureau of Entomology, to undertake a study of their individual life histories and the means for their control.

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[1] *Empoasca mali* (Le Baron); order Hemiptera, suborder Homoptera, family Cicadellidae.

[2] *Empoa rosae* (Linn.); order Hemiptera, suborder Homoptera, family Cicadellidae.

The destructiveness, habits, food plants, and life history of each species are treated separately herein. A detailed account of the experimental work carried out for the control of these two species together with the most efficient remedy is included.

The data on biology and control were obtained at West Chester, Pa., during the seasons of 1915 and 1916, supplemented by field observations at several points in southeastern Pennsylvania, and western Maryland.

THE APPLE LEAFHOPPER, Empoasca mali (Le Baron).

HISTORY.

This species was originally described by Le Baron (1) in 1853[1] under the name *Tettigonia mali,* and it was recorded by him as injurious to fruit trees in Illinois. In 1862 the genus Empoasca was erected by Walsh (2) with a description of three new species, but no mention was made of *mali.* Carlos Berg (3, p. 273), in 1879, described a leafhopper from Argentina as *Typhlocyba phytophila,* and this name later was considered by Gillette to be a synonym of *Empoasca mali.* In 1883 Forbes (4) sent specimens of a green apple leafhopper to Uhler who determined them as belonging to the genus Empoa; subsequently these insects were described by Forbes (5) as a new species, *Empoa albopicta.* Woodworth (6) transferred *Empoa albopicta* Forbes to the genus Empoasca in 1889 and called it *Empoasca albopicta.* The first reference to this species under its correct name, *Empoasca mali,* was made by Gillette (7) in 1890. Osborn (8) and later Gibson (17) mentioned it as injurious to potatoes, and Gillette (9), in 1898, gave the food plants and distribution.

Frequent references to this insect have been made in American entomological literature under the name of "the apple leafhopper" and "the currant leafhopper," by Britton (12), Brues (13), and Garman (16) among others. It has been often referred to as the most injurious leafhopper, both to apple and to various field crops. Washburn (15), in 1908, was the first writer to treat of this insect at any length. He published a record of the seasonal history, food plants, injury, and control of the apple leafhopper as a nursery pest in Minnesota. In 1910 R. L. Webster (18) made a detailed study of the life history and control of this insect on apple nursery stock in Iowa. In 1915 Webster (20) published an account of *Empoasca mali,* treating it as a pest of potatoes.

DISTRIBUTION.

There are no records showing that the apple leafhopper occurs in Europe. In America, outside of the United States, it has been reported from Okanagan, British Columbia, from Nova Scotia, several points in the Province of Ontario, from Mexico, Porto Rico, and Corrientes, Argentina. In the United States this species is widely disseminated, doubtless due to the variety and abundance of its host plants. From specimens in the collection of the United States National Museum, and from the collection, correspondence, and notes of the Bureau of Entomology, it appears to be present in almost every State in the Union. (See fig. 1.) It is found in greatest abundance throughout the eastern humid area of the Upper Austral Zone.

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[1] Figures in parentheses refer to "Literature cited," p. 34.

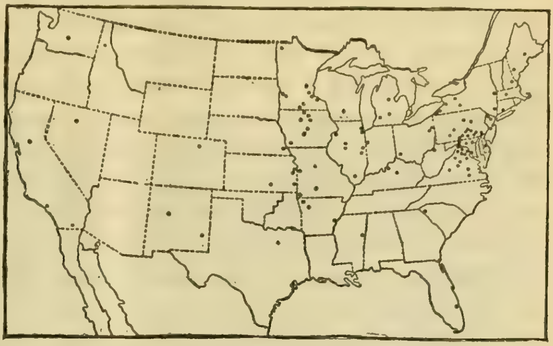


FIG. 1.—Distribution of the apple leafhopper (*Empoasca mali*) in the United States.

FOOD PLANTS.

The food plants of *Empoasca mali* (Le B.) are very numerous and varied. In nurseries this insect prefers apple but it also feeds in great abundance on Norway maple and various oaks. Among field crops it is partial to alfalfa, clover, potato, and beets, in about the order named.

A list of all host plants reported, upon the majority of which the writer has noted this insect feeding, follows:

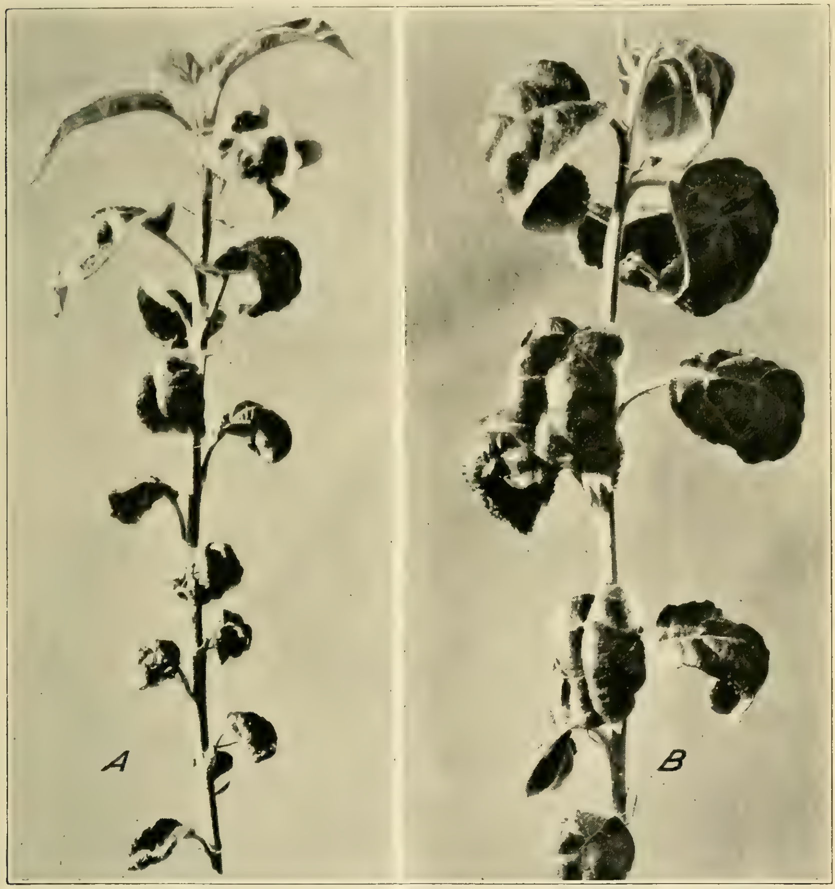
Acer negundo, box-elder.
Acer platanoides, Norway maple.
Althea rosea, hollyhock
Amygdalus persica, peach.
Apium graveolens, celery.
Avena sativa, oats.
Beta vulgaris, beets.
Betula sp., birch.
Cannabis sativa, hemp.
Castanea sp., chestnut.
Corylus americana, hazelnut.
Crataegus sp., hawthorn.
Cydonia oblonga, quince.
Dahlia sp., dahlia.
Gramineae, grasses.
Hamamelis virginiana, witch-hazel.
Hicoria pecan, pecan.
Juglans nigra, black walnut.
Juglans sp., walnut.
Medicago sativa, alfalfa.
Phaseolus vulgaris, beans.
Populus sp., poplar.
Prunus virgianiana, choke-cherry.
Prunus pissardi, purple-leaved plum.
Prunus spp., cherries and plums.
Pyrus baccata, Siberian crab.
Pyrus communis, pear.
Pyrus malus, apple.
Quercus spp., oaks.
Rheum rhaponticum, rhubarb.
Rhus cotinus, smoke-tree.
Ribes oxyacanthoides, gooseberry.
Ribes rubrum, currant.
Rubus spp., blackberry and raspberry.
Rosa spp., roses.
Secale cereale, rye.
Solanum tuberosum, potato.
Sorbus americana, mountain ash.
Sorghum sp., sorghum.
Syringa sp., lilac.
Tilia americana, American linden.
Trifolium sp., clover.
Ulmus americana, American elm.
Viburnum sp., snowball.
Vitis spp., grapes.
Zea sp., corn.

CHARACTER OF INJURY.

The injury caused by the apple leafhopper to nursery apple trees is due to the feeding of the nymphs and adults on the underside of the tender terminal leaves from which they extract the plant juices. As a result of this attack the leaves become undersized and curled (Pl. I, B), causing a decided check to the growth of the new wood. The curling begins at the apex and extends toward the base of the eaves, the lower surface always being rolled in. This type of injury differs from aphis leaf-curl in that aphids roll the leaves more tightly and curl them from the sides instead of from the tips. During the progress of the injury produced by *Empoasca mali* the leaves become wrinkled and the loss of sap finally causes the tips to dry up and turn brown. (See Pl. II, fig. 2.)

The nymphs, because of their greater numbers and due to the fact that they spend the entire nymphal period on a few leaves only, cause more serious injury than do the adults. The latter feed only for a short time, being principally engaged in egg-laying, and during this period they fly from one tree to another. Injury by the feeding of the adults, therefore, is of little importance when compared with the localized injury produced by the nymphs. Consequently, the stunted terminal growth is most apparent at the time when the nymphs are most abundant on the foliage. As the nymphs gradually disappear the terminal shoots seem to revive and develop normal leaves above the stunted ones. (See Pl. I, A.) At the time of infestation by the next brood of nymphs, however, a similar check to the new terminal growth is produced. Thus retardation in growth occurs periodically throughout the season corresponding to the periods of infestation by the successive nymphal broods, while intervening between each infestation there is a short period during which the terminals maintain a normal growth. Although the different broods of nymphs overlap slightly the successive checks in terminal growth usually are well defined.

In the vicinity of West Chester, Pa., there are three broods during the season and three corresponding checks in the terminal growth. The first growth-check takes place during the latter part of June when the first nymphal brood is feeding; a second and a third check appear during the latter part of July and August, respectively, at the time when the second and third broods of nymphs are most active on the foliage. The first brood is the most abundant on apple and consequently causes more injury than do either of the two following broods. Adults of the first brood do not confine their activities to apple alone, as many scatter to other host plants to feed and oviposit.



THE APPLE LEAFHOPPER (EMPOASCA MALI).

A, Terminal leaves of apple shoot outgrowing injury by the leafhopper; *B*, curled condition of terminal leaves caused by the leafhopper.

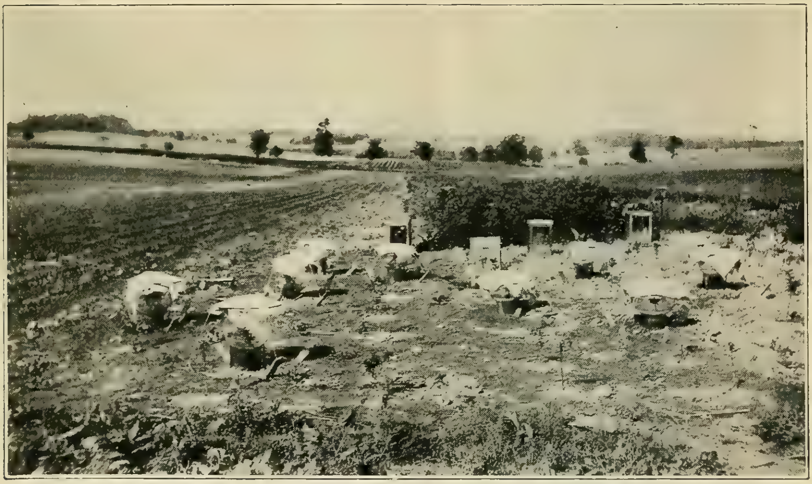


FIG. I.—CAGES USED FOR REARING THE APPLE LEAFHOPPER IN NURSERY, WEST CHESTER, PA.

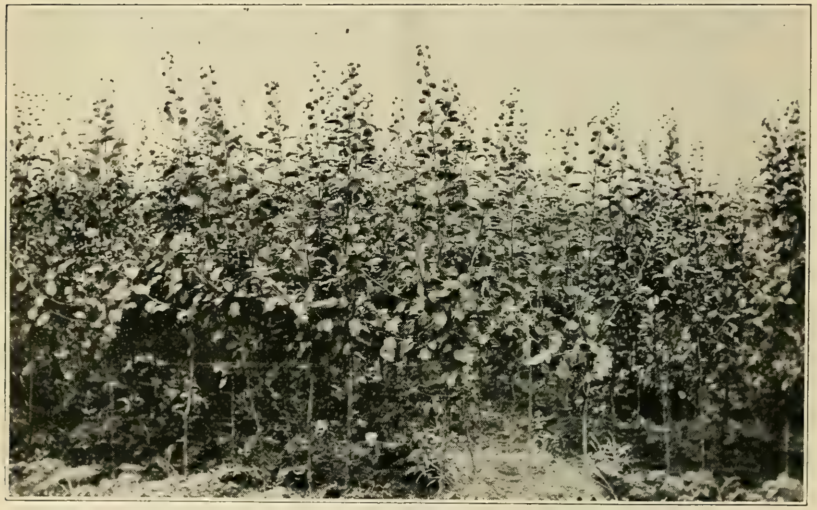
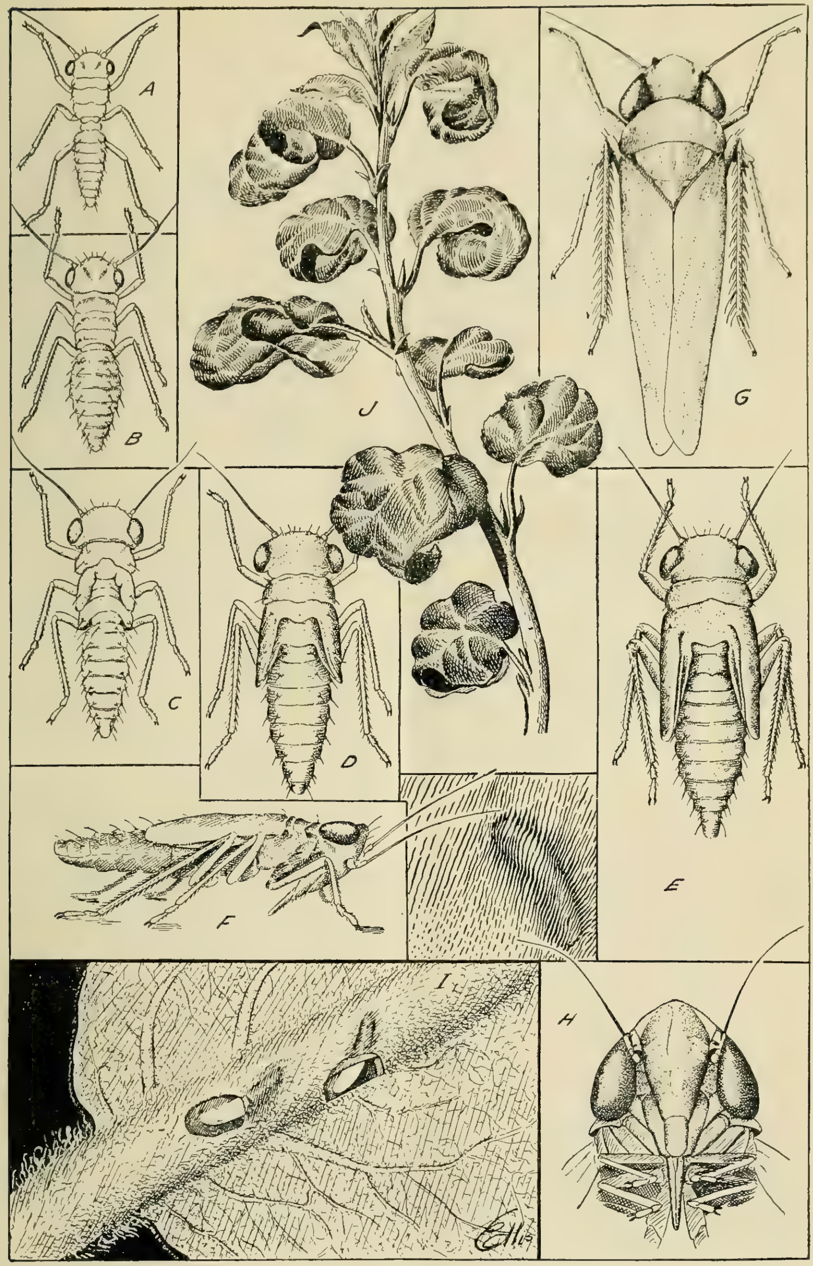


FIG. 2.—TERMINAL LEAVES OF NURSERY APPLE TREES CURLED BY THE APPLE LEAFHOPPER.

THE APPLE LEAFHOPPER.



THE APPLE LEAFHOPPER.

A, First nymphal stage; *B*, second stage; *C*, third stage; *D*, fourth stage; *E*, fifth stage; *F*, side view of fifth stage; *G*, adult; *H*, front view of head of adult; *I*, eggs in tissue on underside of apple leaf; *J*, curled condition of terminal leaves due to attack by the apple leafhopper on apple.

As a result of the continued checking of the growth, due to the infestation of the apple leafhopper, nursery apple trees often require an additional year's growth before they become of marketable size.

EXTENT OF INJURY AND INFLUENCING FACTORS.

The extent of injury varies according to the age of the nursery stock and according to the differences in the character of growth of apple varieties.

Seedlings and the initial growth of buds and grafts are very seriously injured. Nursery stock at this stage is in its most critical period of growth and is injured very easily. Furthermore, any injury at this stage is not readily outgrown.

After the first year's growth the more vigorous varieties become partially immune to serious injury and succeed in maintaining a satisfactory growth, while slow-growing and tender-leaved varieties are at all times badly injured by the attack of this insect. This is easily understood since, even under normal conditions, the latter make but a very ordinary growth and are entirely unable to withstand a serious check. Among the varieties most severely injured in Pennsylvania nurseries Red Astrachan, a particularly slow grower during the first two seasons, ranks first, followed by Smith's Cider, Starr, Early Harvest, Summer Rambo, Delaware Winter, Wagoner, Golden Russet, Early Ripe, Wealthy, and Alexander.

DESCRIPTION OF STAGES.

EGG.

Pl. III, I.

The egg is elongate, subcylindrical in form, very delicate, slightly curved from end to end, somewhat rounded at both ends but more so at the anterior one. When first deposited it is rather transparent but in a few days it changes to a pale yellow color, while a small white cap forms at the anterior end through which the red eyes of the immature nymph are perceptible.

Average length of 15 eggs 0.82 mm., width 0.25 mm.

NYMPH.

Pl. III, A-F.

First instar.—Color pale white, changing to a light yellowish green after feeding. Eyes dull red. Small pale spines on the dorsal side of the head, thorax, and abdomen; the latter with four spines to each segment arranged in two longitudinal rows along each side, one spine situated dorso,laterally, the other ventro-laterally. Posterior margin of metathorax blunt. First two segments of antennæ pale, the remainder dusky. Average length of 16 specimens 1 mm.

Second instar.—General color light yellowish green. Eyes lose some of their red color. Posterior border of metathorax sharp in outline. First two segments of antennæ light yellow, remainder dusky. Average length of 16 specimens 1.30 mm.

Third instar.—General color pale yellowish green. Eyes almost pearl white. Body more robust than in first two stages. Wing pads appear as lateral buds extending to the hind margin of the first abdominal segment. Spines darker and more prominent. Average length of 16 specimens 1.85 mm.

Fourth instar.—Head and thorax yellowish green; abdomen yellow in color. Eyes pearl white. Wing pads extend to hind margin of second abdominal segment. Spines prominent. Average length of 16 specimens 2.1 mm.

Fifth instar.—Head and thorax pale green; abdomen yellow. Eyes dull white. Wing pads extend to or nearly to the hind margin of the fourth abdominal segment. First two antennal segments green, remainder dusky. Body broader than in previous stage. Average length of 16 specimens 2.6 mm.

ADULT.

Pl. III, G, H.

General color of adult pale green; face with a white median longitudinal line in older specimens but composed of a series of white spots in newly hatched individuals; median line extending from a point midway between the ocelli to a point half the distance to lower margin of clypeus; two short white diagonal bands on each side of median line, the lower one the smaller; a short white line, often merely two spots, beyond the diagonal and just above the antenna; a faint white line midway between the ocellus and eye; antennæ 1 mm. in length, arising near the lower frontal border of the eyes; clypeus one-third longer than broad; loræ narrow, not reaching the tips of clypeus, concave below eyes; genæ almost as long and half as broad as clypeus, with one or two faint white spots. Vertex dark green with a median white line, narrowest in middle, its length equal to distance between the ocelli; a white band on each side, dorso-lateral and diagonal to median line. Two ocelli present, marked by two white spots and situated on frontal margin of vertex, their distance apart equal to twice that from the eye to the ocellus; eyes dull white, reddish brown after death. Pronotum pale green, hind margin very pale, with eight white spots along the frontal margin, the last spot at each end small and often fused with the one next to it so as to form only six spots; mesonotum with two parallel white longitudinal lines centrally located and connected by a traverse one in the form of a letter H, a faint white diagonal line present on each lateral margin; scutellum small with a large white triangular area in the center and a small spot on each side along the frontal margin. Abdominal segments yellowish green with transverse yellow stripes on their hind margins, anal segment dark green. Wings semitransparent, pale yellowish green. Legs green, tarsi dusky at the tips. Sexual appendages ciliated in both sexes. Average length of 16 specimens 3.12 mm.

ALLIED SPECIES.

Three other species of Empoasca were found associated with *E. mali* on the foliage of nursery apple trees at West Chester, Pa. These species were determined by the late Otto Heidemann, of the Bureau of Entomology, as follows: *E. birdii* Goding, *E. flavescens* (Fabricius), and *E. unicolor* Gillette. *Birdii* and *flavescens* are very closely allied species, the former being considered by Gillette to be merely a color variety of the latter; these two species resemble *mali* quite closely and they may be easily mistaken for it. *Unicolor,* on the other hand, differs markedly from any of the above three and is readily distinguished from them.

Birdii differs from *mali* by its smaller size and paler color, by the presence of smoky markings on the elytra, and by the three white spots on the pronotum.

No attempt was made to study the life history and habits of *birdii* but they are probably much the same as those of *mali.* From field observations it was found that this species hibernates in the adult stage in woodlands near the nursery at West Chester. The adults become active in the spring about a week earlier than *mali,* confining their feeding at first to the foliage of skunk cabbage. From this plant they scatter to grasses and weeds beneath the apple trees in the nursery a few days prior to the first appearance of *mali.* During the early spring they prefer to feed on any low green vegetation in the nursery row, and never become abundant on the foliage of apple until about mid-season. At this time they appear in numbers associated with *mali* on the terminal leaves. The extent of damage caused by *birdii* is small compared with that caused by the common apple leafhopper, and for this reason little attention has been paid to it heretofore.

Flavescens differs from *birdii* by the absence of the characteristic white markings of the pronotum and the smoky bands crossing the elytra.

This species is allied very closely to *birdii* in appearance, and probably in habits and life history, but it is less abundant on the apple.

Unicolor is readily separated from *mali* by the absence of the conspicuous white markings of the face and the notum, by its greater length and robustness, and by the presence of a pale white spot on the middle of the anterior margin of the pronotum and a blue blotch on the scutellum.

Few field observersations were obtained in regard to the habits of *unicolor.* The nymphs of the first brood were found on apple at approximately the same date and about as abundantly as those of *mali* at Hagerstown, Md. The adults of this species do not confine their attack to the terminal leaves, being found more frequently on the lower part of the trees. This species was taken in scant numbers on apple in the vicinity of West Chester and the injury caused by it was negligible.

LIFE HISTORY AND HABITS.

Methods of Study.

In studying the life history of the two species of apple leafhoppers concerned in this bulletin all data were obtained under outdoor conditions by rearing the insects on young apple stock in the nursery row. Seedlings were planted out early in the spring of 1915 and again in 1916 on a plot of ground at one end of a few nursery rows.

Riley cages and arc-light globe cages (Pl. II, A) were used for obtaining records of the length of the egg stage, the extent of reproduction per female, and the longevity of adults of the different broods. The globe cages were well shaded from the sun by means of large muslin covers over their tops, while ventilation was obtained both from above and below. With the use of such cages practically normal conditions were secured for the rearing of the leafhopper material. The plants were encaged before the hibernating adults made their appearance in the nursery, thereby preventing outside infestation.

Special cages were constructed for experiments in determining the length of the nymphal stages. Various types of cages were tried in an effort to secure one in which the nymph could be reared under as nearly normal conditions as possible.

The type of cage finally decided upon was made as follows: A piece of thin sheet-cork was cut about 2 inches square, in the center of which a 1-inch square hole was made. White muslin cloth was stretched tightly over one side of the cork and glued fast so as to cover the center hole. Heavy wadding cut to the shape of the cork, but leaving the center open, was glued to the other side. With the muslin side out, the cage was then placed over a newly hatched nymph on the lower surface of a leaf. A square of stiff cardboard of the same size as the cork was placed on the upper side of the leaf, and the cardboard, leaf, and cage were fastened together by paper clips. The young nymph within the cage received ventilation from both sides, through the porous wadding and through the muslin top. The leaf tissue was protected against injury by the cardboard on its upper surface and by the wadding on its lower surface. The nymph was examined daily by removing the paper clips and lifting the cage slightly; in this manner a record of the molts was obtained.

Although this cage was a little heavy when used on the small leaves of seedlings, it proved satisfactory when fastened to the larger leaves of two-year trees. For this reason the nymphal stages were obtained by transferring newly hatched nymphs from globe cages to the cork cages on uninfested leaves of older trees in the nursery row.

Number of Generations.

There are three generations of the apple leafhopper at West Chester, Pa. These generations overlap slightly but they are easily distinguished by the resultant injury caused by each. The first generation, covering the period from the time of egg deposition by the overwintered females to the death of the first-brood adults, extends from the last week in May to the first week in August. The second generation covers the period from the first week in July until the latter part of September. The third generation, including the hibernating adults, lasts from the first week in September until the early part of July of the following season. Adults of this generation hatch during the first week in September and remain on the trees until late in November when they seek shelter for the winter. In the spring of the following year overwintered adults are found on the trees from the last week in May until death, which occurs during June and early July.

Forbes and Hart (10) in 1900 mentioned the occurrence of four or more generations in Illinois. In 1908 Washburn (15) suggested that there were two and possibly three generations in Minnesota. R. L. Webster (18) in 1910 recorded four generations at Ames, Iowa. E. H. Gibson, of the Bureau of Entomology, has noted as many as five generations in southern Missouri, and six in southern Mississippi.

The Egg.

The eggs are laid singly in the sides of the mid-vein and occasionally in the smaller veins of the terminal leaves. They are deposited in pockets just under the epidermis, usually lying in a longitudinal position. It is very difficult to locate the eggs as they are the same color as the tissue in which they are embedded, while the epidermis under which they are hidden is covered by the pubescence of the leaf. When the pubescence is removed, the tissue covering the egg appears slightly distorted and eventually becomes discolored. In making dissections of the leaf tissue the delicate egg is often crushed, whereupon the egg contents may be mistaken for the plant juice in the vein. When ready to hatch, the immature nymph pushes its head through the anterior end of the eggshell and forces a tiny hole in the thin epidermal leaf-covering, slowly drawing its body free from the enveloping tissue.

Eggs of *Empoasca mali* have been found in the leaves of the following host plants: Apple, pear, peach, plum, cherry, quince, alfalfa, beet, and potato.

Adults of all three generations deposit summer eggs in leaves in the manner mentioned above. Washburn (15) stated in 1908 that the last-brood adults of this species deposit winter eggs under the bark of nursery apple trees in Minnesota, and that the nymphs hatching therefrom the following spring attack the lower leaves of the trees. Webster (18) in 1910 made similar observations in Iowa. At West Chester, Pa., the apple leafhopper certainly does not pass the winter in the egg stage. Several experiments were made in the attempt to obtain winter eggs by confining numerous pairs of third-brood adults in cages, but all proved unsuccessful. Field observations for two seasons on several thousand trees also substantiate the above view. However, winter eggs of the rose leafhopper (which will be treated later) were found in abundance in this locality, the nymphs of which confine their feeding to the lower leaves of the trees.

The Nymph.

The newly-hatched nymphs are very small, wingless, white in color, and of the same form as the adults. Immediately after hatching they settle down to feed, inserting their minute beaks in the leaf tissue and sucking the plant juices. A day or two after taking food into their bodies the young nymphs change to a pale green color, which is the characteristic color during the remainder of their nymphal life. The nymphs pass through five stages of development before they reach maturity, molting and increasing in size at the completion of each stage. The nymphs are very agile in their movements and run in a zig-zag or sidling manner; only fourth and fifth stage nymphs are able to hop.

The first nymphs of the season appear on the trees about June 1, and the nymphal infestation is at its height about three weeks later.

THE ADULT.

The adults are very active, especially on warm, sunny days, when they rise from the trees in swarms at the least disturbance. During flight the hoppers seldom rise over the tops of the trees but fly sidewise to the next nursery row.

Records have appeared stating that this insect is strongly attracted to artificial light, but this view is contrary to observations made by the writer. Among the leafhoppers found swarming around electric lights the two allied species *E. flavescens* and *E. birdii* were far more abundant than this species.

The overwintered adult leafhoppers become active during the warm days about the middle of May. Upon leaving their hibernating places they immediately disperse to apple blocks in the nursery. The first adults of the season appearing on apple stock in the nursery were found on May 18; by June 1 they become quite abundant on the foliage in this section. For several days they confine their activities to feeding on the underside of the terminal leaves. After feeding for about a week the adults mate and soon begin depositing the first-brood eggs.

Adults of all three generations have the same habits on apple. Third-brood adults feed on apple foliage in the fall until cold weather sets in. Prior to going into hibernation they collect on the lower leaves of the trees and on several varieties of low-growing weeds in the nursery row, being especially abundant on sorrel (*Rumex* sp.).

LONGEVITY OF OVERWINTERED ADULTS.

Data on the length of life of the adult apple leafhoppers were obtained with great difficulty, due to their activity. A Riley cage was used in this experiment in which 50 adults were confined on a young apple tree. The newly transforming nymphs were removed from the foliage from time to time to prevent confusing them with the adults. During the progress of the examinations a few adults made their escape. A record of the date on which the adults died is given in Table I. It will be noted that death occurred in most cases by July 1. From observations in the field it was found that practically all overwintered adults had disappeared from the trees by the first week in July.

TABLE I.—*Longevity of overwintered adult apple leafhoppers; 50 adults placed in cage June 8, 1915.*

Date of examination.	Number dead.	Date of examination.	Number dead.
June 20	4	June 30	1
June 21	1	Do	[1]4
June 22	6	July 1	1
Do	[1]1	July 3	1
June 23	2	July 12	1
June 24	4	July 13	2
June 25	5	July 14	1
June 26	1	July 15	2
June 27	3	July 16	1
Do	[1]1	July 17	1
June 28	2	July 18	1
June 29	2	July 19	2

[1] Escaped.

EXTENT OF REPRODUCTION BY OVERWINTERED FEMALES.

Pairs of overwintered adults were placed on young trees in globe cages to determine the number of eggs deposited by a female in confinement. The adult leafhoppers were allowed to remain on the foliage until they died. Examinations were made from time to time and a record was kept of the number of nymphs removed at each examination. This method of obtaining the extent of reproduction does not take into consideration the number of eggs that failed to hatch; however, it shows approximately the number of eggs deposited by a single female.

Two experiments were carried out and averages of 27 and 28 eggs per female hatched in the respective cages. In Table II the number of nymphs removed is given.

TABLE II.—*Number of first-brood nymphs produced by overwintered adult apple leafhoppers in confinement, West Chester, Pa., 1915.*

CAGE NO. 1.—TWO PAIRS OF OVERWINTERED ADULTS PLACED IN CAGE ON YOUNG APPLE TREE JUNE 9, 1915.

Date of examination.	Number of first-brood nymphs removed.	Date of examination.	Number of first-brood nymphs removed.
June 24	43	July 7	2
June 26	2	July 30	0
June 29	6		
July 1	1	Average	27

CAGE NO. 2.—THREE PAIRS OF OVERWINTERED ADULTS PLACED IN CAGE ON YOUNG APPLE TREE JUNE 7, 1915.

June 24	31	July 7	10
June 26	14	July 10	1
June 29	15	July 20	3
June 30	4	July 30	0
July 1	1		
July 3	5	Average	28

FIRST GENERATION.

FIRST BROOD OF EGGS.

Length of incubation period.—The adult females are very rarely seen depositing eggs since they are very agile in their movements and take flight at the slightest disturbance. Moreover, even though a female is observed in the act of oviposition, the egg is seldom detected, as it is inserted under the epidermis and is further hidden by the downy pubescence of the leaf. For these reasons only approximate records of the length of the egg stage could be secured.

Data on the incubation period were obtained by confining copulating pairs of overwintered adults on a seedling tree in a globe cage. The adults were removed after 24 hours and a daily record was kept of the nymphs as they hatched. The length of the egg stage, together with the average mean temperature for the entire period, is given in Table III. The average incubation period was 7.5 to 9.5 days; the maximum, 10 to 12 days; the minimum, 5 to 7 days.

TABLE III.—*Length of incubation period of first-brood eggs deposited by overwintered females of the apple leafhopper in confinement, West Chester, Pa., 1915.*

TWENTY PAIRS OF OVERWINTERED ADULTS PLACED ON APPLE TREE JUNE 13, 1915, 12 M.; ADULTS REMOVED JUNE 14, 12 M.

Date of removal of newly hatched nymphs.	Number of nymphs removed.	Length of incubation period.	Average temperature for entire period.
1915.		*Days.*	°*F.*
June 20, 12 m	2	5 – 7	79.56
June 21, 12 m	47	6 – 8	78.61
June 22, 12 m	30	7 – 9	77.00
June 23, 12 m	10	8 –10	75.90
June 24, 12 m	4	9 –11	75.20
June 25, 12 m	1	10 –12	75.07
Average		7.5– 9.5	76.89

FIRST BROOD OF NYMPHS.

Length of stages.—The length of the nymphal stages and of the entire nymphal period was obtained by confining newly hatched nymphs in the cork cages described on page 8. Each cage was examined daily and a record made of the length of each stage, the cast skins being removed from the cages after each molt. The length of each stage and of the entire nymphal period is shown in Table IV; the average mean temperature for each nymphal period is also included. The average length of the nymphal period for 22 nymphs was 18.7 days; the maximum, 22 days; the minimum, 15 days.

TABLE IV.—*Length of nymphal stages of the first brood of the apple leafhopper at West Chester, Pa., 1915.*

First brood, June and July.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average mean temperature for nymphal period.
1915.	1915.	*Days.*	1915.	*Days.*	1915.	*Days.*	1915.	*Days.*	1915.	*Days.*	*Days.*	°*F.*
June 12	June 15	3	June 17	2	June 21	4	June 25	4	June 30	5	18	75.18
Do...	June 16	4	June 18	2	...do....	3	June 26	5	July 1	5	19	75.47
Do...	June 18	6	June 21	3	June 25	4	June 29	4	July 3	4	21	75.79
Do...	June 16	4	June 19	3	June 22	3	June 27	5	July 1	4	19	75.47
June 13	...do....	3	June 20	4	June 24	4	...do.....	3	July 2	5	19	75.20
Do...	June 17	4	...do.....	3	June 21	1	June 26	5	July 1	5	18	75.15
Do...	June 18	5	...do.....	2	...do.....	1	June 27	6	July 4	7	21	75.70
Do...	June 16	3	...do.....	4	June 25	5	June 29	4	July 3	4	20	75.52
Do...	June 18	5	...do.....	2	June 23	3	June 27	4	July 2	5	19	75.20
June 14	June 16	2	June 19	3	June 21	2	June 29	8	July 3	4	19	75.20
Do...	June 17	3	June 20	3	June 24	4	June 28	4	July 2	4	18	74.84
Do...	June 18	4	...do.....	2	June 23	3	...do.....	5	July 3	5	19	75.20
Do...	...do....	4	June 21	3	June 29	8	July 2	3	July 6	4	22	75.28
Do...	June 17	3	...do.....	4	June 23	2	June 26	3	July 1	5	17	74.77
June 15	June 18	3	...do.....	3	June 24	3	June 28	4	July 3	5	18	74.81
Do...	...do....	3	...do.....	3	June 25	4	June 29	4	July 4	5	19	75.05
Do...	June 19	4	...do.....	2	June 24	3	June 28	4	July 1	3	16	74.32
Do...	...do....	4	June 22	3	June 27	5	July 1	4	July 6	5	21	74.95
June 18	June 21	3	June 26	5	June 29	3	July 3	4	...do....	3	18	74.36
Do...	June 20	2	June 24	4	...do.....	5	July 2	3	...do...	4	18	74.36
June 19	June 21	2	...do.....	3	June 26	2	June 29	3	July 4	5	15	74.06
June 23	June 26	3	June 30	4	July 4	4	July 8	4	July 11	3	18	75.07
Average	....	3.5	....	3	....	3.4	....	4.2	....	4.5	18.7	75.04

FIRST BROOD OF ADULTS.

Longevity.—First-brood adults were confined in a Riley cage to determine the length of life. Most of the hoppers died by August 1, as shown in Table V.

TABLE V.—*Longevity of first-brood adult apple leafhoppers; 50 adults placed in cage July 2, 1915.*

Date of examination.	Number dead.	Date of examination.	Number dead.
July 7	6	July 24	[1] 2
July 8	3	July 26	2
July 9	6	July 27	3
July 10	1	July 30	4
Do	[1] 2	July 31	1
July 11	2	Aug. 2	3
July 12	1	Aug. 4	2
July 13	3	Aug. 5	1
July 17	5	Do	1
July 24	1	Aug. 6	1

[1] Escaped.

Extent of reproduction.—Two globe cage experiments were made to determine the extent of reproduction by a first-brood female in confinement. In one cage two pairs of adults, in the other three pairs were confined until death occurred. The average number of eggs deposited per female in cage 1 was approximately 24; in cage 2, approximately 22. (See Table VI.)

TABLE VI.—*Number of second-brood nymphs produced by first-brood adult apple leafhoppers in confinement, West Chester, Pa., 1915.*

CAGE NO. 1.—TWO PAIRS OF FIRST-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE JUNE 30, 1915.

Date of examination.	Number of second-brood nymphs removed.	Date of examination.	Number of second-brood nymphs removed.
July 13	14	July 27	1
July 17	1	July 30	1
July 20	22	Aug. 10	0
July 22	8		
July 24	1	Average	24

CAGE NO. 2.—THREE PAIRS OF FIRST-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE JUNE 30, 1915.

July 14	6	July 29	11
July 17	3	July 30	3
July 20	17	Aug. 10	0
July 22	6		
July 24	5	Average	22
July 27	15		

SECOND GENERATION.

SECOND BROOD OF EGGS.

Length of incubation period.—As will be noted in Table VII, the length of the egg stage of this brood is somewhat shorter than that of the first brood. This fact undoubtedly is due to the higher temperatures occurring throughout the incubation period of the second-brood eggs. As in Table III only an approximation of the length of the incubation period was obtained. The average incubation period of second-brood eggs was 6 to 8 days; the maximum, 9 to 11 days; the minimum, 3 to 5 days.

TABLE VII.—*Length of incubation period of second-brood eggs of the apple leafhopper, West Chester, Pa., 1915.*

TWENTY-FIVE PAIRS OF FIRST-BROOD ADULTS PLACED ON APPLE TREE JULY 7, 1915, 3 P. M.; ADULTS REMOVED JULY 8, 3 P. M.

Date of removal of newly hatched nymphs.	Number of nymphs removed.	Length of incubation period.	Average temperature for entire period.
1915.		*Days.*	*°F.*
July 12, 3 p. m	9	3– 5	77.08
July 13, 3 p. m	8	4– 6	77.42
July 14, 3 p. m	6	5– 7	77.50
July 15, 3 p. m	15	6– 8	77.66
July 16, 3 p. m	13	7– 9	78.05
July 17, 3 p. m	12	8–10	78.86
July 18, 3 p. m	1	9–11	79.54
Average		6– 8	78.01

SECOND BROOD OF NYMPHS.

Length of stages.—The length of the stages and of the entire nymphal period of this brood was slightly shorter than in the case of first-brood nymphs. Table VIII shows that the average nymphal period of second-brood nymphs was 15.8 days; the maximum, 17 days; the minimum, 15 days.

TABLE VIII.—*Length of nymphal stages of the second brood of the apple leafhopper at West Chester, Pa., 1915.*

SECOND BROOD, JULY AND AUGUST.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average mean temperature for nymphal period.
1915.	1915.	*Days.*	1915.	*Days.*	1915.	*Days.*	1915.	*Days.*	1915.	*Days.*	*Days.*	°*F.*
July 14	July 17	3	July 19	2	July 22	3	July 25	3	July 30	5	16	79.70
July 17	July 19	2	July 23	4	July 26	3	July 30	4	Aug. 3	4	17	80.22
Do...	July 20	3	July 22	2	July 24	2	July 28	4	Aug. 1	4	15	80.50
July 20	July 22	2	July 23	1	July 27	4	July 30	3	Aug. 5	6	16	79.05
Do...	...do....	2	July 25	3	July 28	3	...do....	2	Aug. 4	5	15	79.00
Do...	...do....	2	...do....	3	July 29	4	Aug. 1	3	Aug. 5	4	16	79.05
July 21	July 24	3	July 28	4	July 31	3	Aug. 3	3	Aug. 7	4	17	78.27
July 22	July 25	3	July 29	4	...do....	2	Aug. 2	2	Aug. 6	4	15	79.40
July 23	...do....	2	...do....	4	July 30	1	...do....	3	Aug. 7	5	15	78.56
Do...	July 26	3	...do....	3	...do....	1	Aug. 3	4	Aug. 8	5	16	78.52
Do...	July 25	2	July 28	3	...do....	2	Aug. 2	3	Aug. 7	5	15	78.56
Do...	July 26	3	...do....	2	...do....	2	Aug. 3	4	Aug. 8	5	16	78.52
Do...	...do....	3	July 27	1	...do....	3	...do....	4	...do...	5	16	78.52
Do...	July 27	4	July 29	2	Aug. 1	3	Aug. 5	4	Aug. 9	4	17	78.38
Average	....	2.6	....	2.7	....	2.5	....	3.2	....	4.6	15.8	79.01

SECOND BROOD OF ADULTS.

Longevity.—In Table IX the date of death for 40 second-brood adults is recorded.

TABLE IX.—*Longevity of second-brood adults; 40 adults placed in cage Aug. 13, 1915.*

Date of examination.	Number dead.	Date of examination.	Number dead.
Aug. 17	4	Sept. 16	1
Aug. 23	2	Sept. 20	2
Aug. 26	10	Sept. 24	2
Sept. 1	4	Sept. 27	3
Do	[1] 3	Sept. 30	2
Sept. 13	5	Do	[1] 1
Do	[1] 1		

[1] Escaped.

Extent of reproduction.—Four separate experiments were made to determine the number of eggs deposited by a female of the second brood. Two, three, four, and five pairs of adults, respectively, were placed in separate cages and a record of the number of eggs hatched was kept. The average number of eggs deposited per female was 19.5 in cage 1, 21 in cage 2, 20.2 in cage 3, and 18.4 in cage 4. The total average for the four cages was 19.8 eggs per female. (See Table X.)

TABLE X.—*Number of third-brood nymphs produced by second-brood adult apple leafhoppers in confinement.*

CAGE NO. 1.—TWO PAIRS SECOND-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE AUG. 5, 1915.

Date of examination.	Number of third-brood nymphs removed.	Date of examination.	Number of third-brood nymphs removed.
Aug. 16	21	Sept. 7	0
Aug. 23	12		
Aug. 30	6	Average per female	19.5

CAGE NO. 2.—THREE PAIRS SECOND-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE AUG. 5, 1915.

Aug. 16	12	Sept. 14	3
Aug. 23	29	Sept. 28	0
Aug. 31	14		
Sept. 4	5	Average per female	21

CAGE NO. 3.—FOUR PAIRS SECOND-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE AUG. 5, 1915.

Aug. 16	37	Sept. 14	5
Aug. 23	24	Sept. 28	0
Aug. 31	8		
Sept. 4	7	Average per female	20.2

CAGE NO. 4.—FIVE PAIRS SECOND-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE AUG. 9, 1915.

Aug. 23	34	Sept. 22	1
Aug. 31	18	Sept. 30	0
Sept. 4	25		
Sept. 14	14	Average per female	18.4

THIRD GENERATION.

THIRD BROOD OF EGGS.

Length of incubation period.—Three separate cages were used in the experiments on the length of the incubation period of third-brood eggs. The average incubation period was 9.6 to 10.3 days for cage 1; 9.5 to 11.5 days for cage 2; and 10 to 12 days for cage 3. (See Table XI.)

TABLE XI.—*Length of incubation period of third-brood eggs of the apple leafhopper, West Chester, Pa., 1915.*

CAGE NO. 1.—SIX PAIRS OF ADULTS PLACED ON APPLE TREE AUG. 6, 1915, 8 A. M.; ADULTS REMOVED AUG. 6, 4 P. M.

Date of removal of newly hatched nymphs.	Number of nymphs removed.	Incubation period.	Average temperature for entire period.
1915.		*Days.*	°*F*
Aug. 15, 4 p. m.	12	8.6- 9.3	75.95
Aug. 16, 4 p. m.	2	9.6-10.3	76.40
Aug. 17, 4 p. m.	2	10.6-11.3	76.00
Average	....	9.6-10.3	76.11

CAGE NO. 2.—TEN PAIRS OF ADULTS PLACED ON APPLE TREE AUG. 9, 1915, 4 P. M.; ADULTS REMOVED AUG. 10, 4 P. M.

1915.		*Days.*	°*F*
Aug. 19, 4 p. m.	11	8-10	75.15
Aug. 20, 4 p. m.	16	9-11	75.00
Aug. 21, 4 p. m.	5	10-12	74.87
Aug. 22, 4 p. m.	3	11-13	75.07
Average	....	9.5-11.5	75.02

CAGE NO. 3.—TWENTY-FIVE PAIRS OF ADULTS PLACED ON APPLE TREE AUG. 13, 1915, 4 P. M.; ADULTS REMOVED AUG. 14, 3 P. M.

1915.		*Days.*	°*F*
Aug. 23, 4 p. m.	6	8-10	74.65
Aug. 24, 4 p. m.	43	9-11	74.95
Aug. 25, 4 p. m.	38	10-12	74.70
Aug. 26, 4 p. m.	9	11-13	74.57
Aug. 27, 4 p. m.	3	12-14	73.89
Average	....	10-12	74.55

TABLE XII.—*Length of nymphal stages of the third brood of the apple leafhopper at West Chester, Pa., 1915.*

THIRD BROOD, AUGUST AND SEPTEMBER.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average mean temperature for nymphal period.
1915.	1915.	*Days.*	1915.	*Days.*	1915.	*Days.*	1915.	*Days.*	1915.	*Days.*	*Days.*	°*F.*
Aug. 12	Aug. 14	2	Aug. 17	3	Aug. 20	3	Aug. 22	2	Aug. 27	5	15	74.44
Do.	Aug. 16	4	Aug. 19	3	Aug. 21	2	Aug. 25	4	Aug. 30	5	18	73.10
Do.	Aug. 15	3	...do.....	4	Aug. 22	3	...do.....	3	Aug. 31	6	19	72.55
Do.	Aug. 16	4	...do.....	3	Aug. 23	4	Aug. 27	4	Sept. 3	7	22	72.32
Aug. 14	Aug. 15	1	Aug. 18	3	Aug. 21	3	Aug. 24	3	Aug. 30	6	16	72.50
Do.	Aug. 16	2	Aug. 19	3	Aug. 22	3	Aug. 25	3	Aug. 31	6	17	71.94
Do.	...do....	2	...do.....	3	...do.....	3	...do.....	3	Sept. 1	7	18	71.78
Do.	...do....	2	...do.....	3	Aug. 23	4	Aug. 27	4	Sept. 2	6	19	71.52
Do.	Aug. 17	3	...do.....	2	Aug. 24	5	Aug. 26	2	Sept. 1	6	18	71.78
Aug. 17	Aug. 20	3	Aug. 23	3	Aug. 26	3	Aug. 31	5	Sept. 6	6	20	71.76
Do.	...do....	3	Aug. 22	2	Aug. 25	3	...do.....	6	...do....	6	20	71.76
Do.	Aug. 21	4	Aug. 23	2	...do.....	2	Sept. 1	7	...do....	5	20	71.76
Do.	...do....	4	...do.....	2	Aug. 26	3	...do.....	6	Sept. 7	6	21	72.09
Do.	Aug. 20	3	Aug. 22	2	Aug. 25	3	...do.....	7	Sept. 6	5	20	71.76
Average	....	2.8	....	2.7	....	3.1	....	4.2	....	5.8	18.7	72.21

THIRD BROOD OF NYMPHS.

Length of stages.—The average nymphal period was 18.7 days; the maximum, 22 days; the minimum, 15 days. (See Table XII.)

THIRD BROOD OF ADULTS.

Attempt to rear a fourth brood of nymphs.—Third-brood adults which were reared in confinement were placed on young apple trees in globe cages in an attempt to rear a fourth brood of nymphs. Four experiments were carried out, pairs of adults being confined on August 24, September 14 and 30, and October 1. None of the adults was observed to mate and not a single fourth-brood nymph developed. The foliage was examined several times covering a period of six weeks or more after the adults were confined.

Number of winter eggs deposited.—Four globe cage experiments were conducted to determine whether the third and last brood adults of the apple leafhopper deposited winter eggs in the bark of apple trees. Pairs of adults were confined in four separate cages on August 24, September 14, September 30, and October 1. They were allowed to remain undisturbed on the trees until December 10, when the trees were brought into the laboratory and carefully examined for winter eggs under the bark. Not a single winter egg was found on any of the four trees.

TABLE XIII.—*Daily maximum, minimum, and average temperatures taken at West Chester, Pa., from May 12 to Sept. 18, 1915.*

Day of month.	May.			June.			July.			August.			September.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
1	......	......	......	80	64	72	86	76	81	96	82	89	72	66	69
2	......	......	......	60	54	57	84	68	76	91	79	85	73	66	69.5
3	......	......	......	59	48	53.5	88	76	82	75	67	71	81	66	73.5
4	......	......	......	80	59	69.5	84	75	79.5	84	76	80	83	72	77.5
5	......	......	......	84	70	77	80	72	76	83	77	80	84	74	79
6	74	67	70.5	75	70	72.5	76	68	72	80	70	75	86	76	81
7	77	65	71	84	71	77.5	82	72	77	68	63	65.5	86	74	80
8	70	60	65	80	70	75	80	68	74	84	72	78	86	71	78.5
9	63	54	58.5	76	66	71	83	66	74.5	82	70	76	86	78	82
10	66	55	60.5	76	61	68.5	86	76	81	80	70	75	90	76	83
11	68	58	63	84	74	79	80	73	76.5	80	72	76	86	78	82
12	72	60	66	88	75	81.5	87	72	79.5	79	71	75	84	74	79
13	80	59	69.5	86	78	82	84	75	79.5	85	78	81.5	88	82	85
14	81	60	70.5	89	76	82.5	85	71	78	84	73	78.5	88	80	84
15	79	54	66.5	84	72	78	84	74	79	84	74	79	86	80	83
16	62	50	56	83	75	79	89	74	81.5	85	77	81	88	76	82
17	71	62	66.5	84	74	79	91	83	87	75	68	71.5	88	74	81
18	61	50	55.5	83	77	80	92	82	87	70	58	64	81	70	75.5
19	74	52	63	83	76	79.5	90	82	86	76	64	70	......	......	......
20	75	64	69.5	80	73	76.5	79	72	75.5	82	65	73.5	......	......	......
21	66	59	62.5	77	65	71	78	68	73	76	71	73.5	......	......	......
22	84	69	76.5	65	60	62.5	84	74	79	83	72	77.5	......	......	......
23	72	66	69	69	61	65	81	68	74.5	83	73	78	......	......	......
24	70	58	64	75	60	67.5	80	74	77	84	72	78	......	......	......
25	76	68	72	81	66	73.5	84	74	79	76	68	72	......	......	......
26	77	60	68.5	84	69	76.5	84	72	78	76	70	73	......	......	......
27	79	64	71.5	78	68	73	82	69	75.5	70	60	65	......	......	......
28	70	66	68	78	65	71.5	82	74	78	66	62	64	......	......	......
29	69	63	66	78	67	72.5	86	78	82	66	60	63	......	......	......
30	79	71	75	80	75	77.5	90	80	85	74	68	71	......	......	......
31	80	70	75	......	......	......	91	74	82.5	68	57	62.5	......	......	......

The foregoing experiments indicate that third-brood adults of the apple leafhopper, under Pennsylvania conditions, do not deposit winter eggs, but merely feed on the foliage until the time arrives for them to seek shelter for the winter.

The daily temperature for the period of seasonal activity is given in Table XIII.

SUMMARY OF SEASONAL HISTORY.

The apple leafhopper passes the winter in the adult stage under rubbish in the nursery or more often under accumulations of leaves in adjoining woodlands. In the spring the overwintered adults make their appearance on the trees during the latter part of May and they feed on the underside of the terminal leaves for about 10 days before mating. The females deposit their eggs in the veins of the terminal leaves, the average length of the incubation period of the first-brood eggs being approximately one week. The feeding period of this brood of nymphs extends from May 30 until about the middle of July, the nymphs being most abundant during the third week in June. The length of the first-brood nymphal period varies from 15 to 22 days, the average being 18.7 days. First-brood adults continue to emerge from June 20 to July 20. (See fig. 2.)

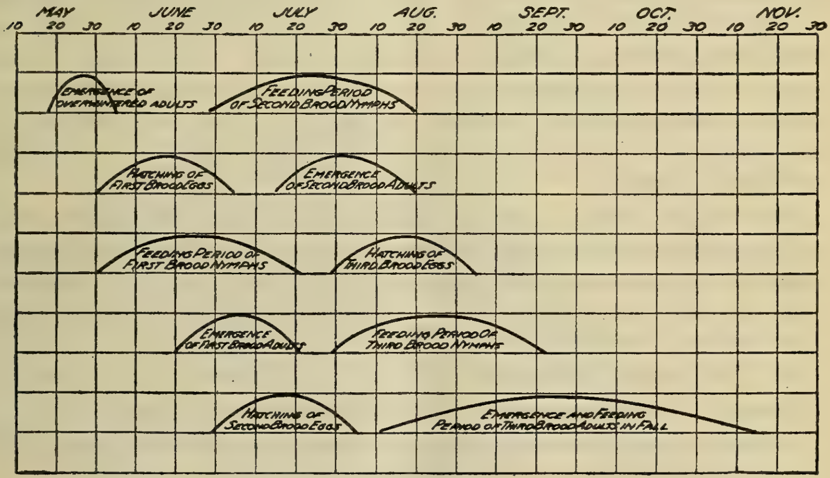


FIG. 2.—Seasonal history of the apple leafhopper at West Chester, Pa., 1915.

Second-brood eggs hatch from the latter part of June until about August 1, the length of the incubation period being about one week. The second-brood nymphs commence to appear about the last part of June, the larger percentage having developed into adults by the middle of August. The average length of the second nymphal period is 15.8 days; the maximum and minimum, 17 and 15 days, respectively. Second-brood adults appear on the trees from the middle of July until about a month later.

The third-brood eggs hatch from July 30 until about September 1, the length of the egg stage of this brood being about 9 to 10 days. Third-brood nymphs are found on the foliage from August 1 until about the third week in September, the average length of the entire nymphal period being 18.7 days or approximately the same as that of the first brood. By the middle of August the nymphs begin to transform to adults and by the end of September all the nymphs have disappeared. The third-brood adults remain on the trees until cold weather sets in when they gradually disperse to the hibernating places.

NATURAL ENEMIES.

The apple leafhopper is evidently quite free from the attack of parasites. Only one record of parasitism has appeared in the literature, R. L. Webster in 1913 having noted the pupa of an egg parasite which, however, died before reaching maturity.

A few cases of parasitism of adults by a dryinid have been seen at West Chester, Pa., but no adults of this parasite were reared successfully. However, two dryinid females were captured in the field while in the act of ovipositing in the abdomen of nymphs of *Empoasca mali*. These specimens were determined by Mr. J. C. Crawford, of the United States National Museum, as *Aphelopus albopictus* Ashm.

Probably the most effective enemy of this leafhopper is the predacious heteropteron *Triphleps insidiosus* Say. This small black insect, which is rather common on the foliage during midsummer, feeds on the nymphs by thrusting its beak into their soft bodies. It is actually of little importance, however, in reducing the numbers of leafhopper nymphs.

Spiders and various species of mites have been noted attacking and devouring nymphs on several occasions. In one instance an adult of the pear-leaf blister-mite was found preying on a first-stage nymph. Ladybeetle larvæ also are predacious on nymphs to a small extent.

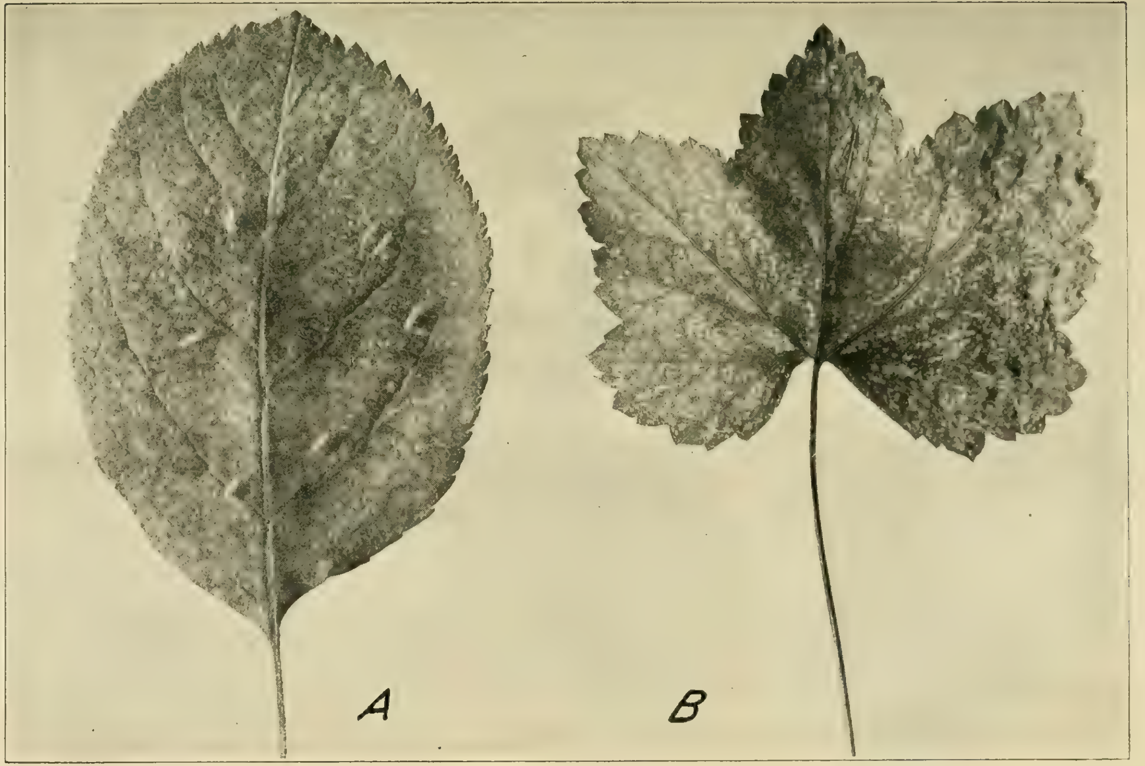
R. L. Webster (18) records larvæ of aphis lions and a dipteron of the family Empididae as feeding on the nymphs in Iowa.

As in the case of other species of leafhoppers, both the nymphs and the adults are often caught in spider webs.

THE ROSE LEAFHOPPER, Empoa rosae (Linn.).

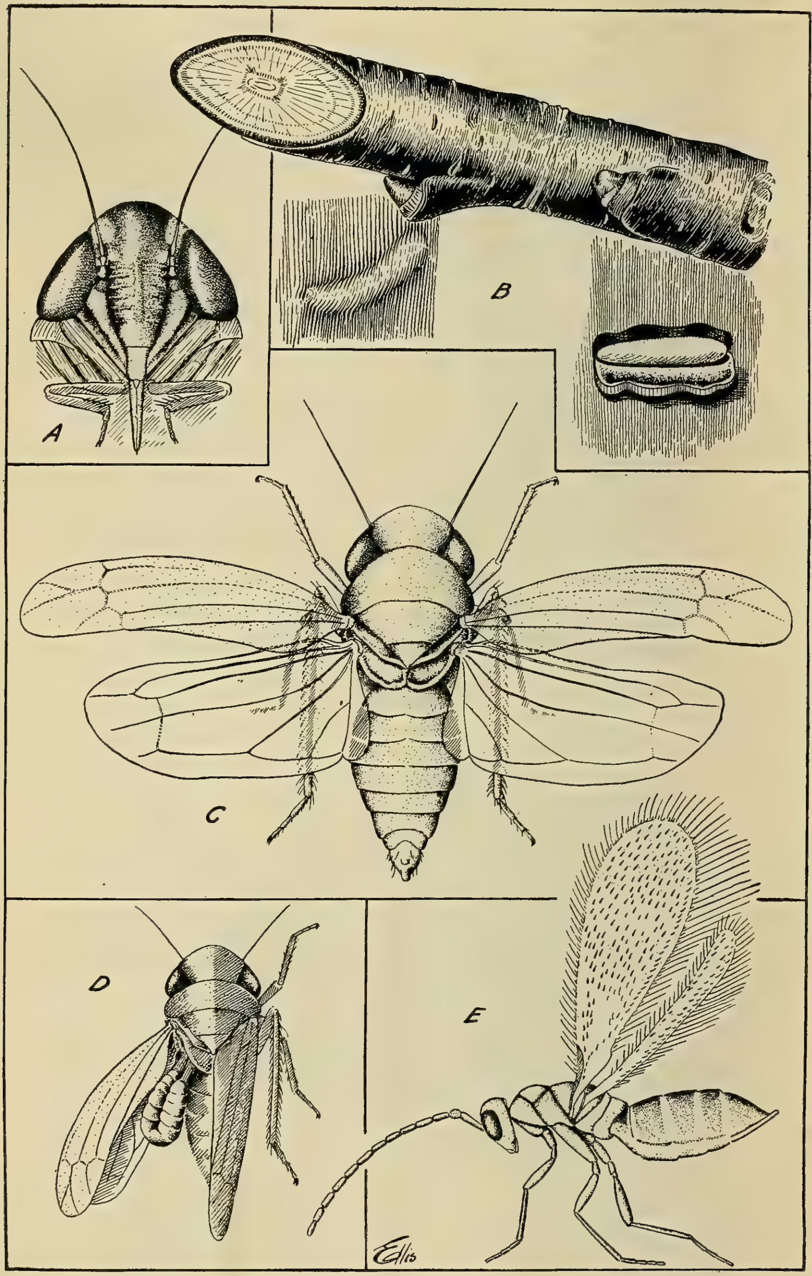
HISTORY.

The rose leafhopper was originally described by Linnaeus (21, p. 439) in Europe in 1758 as *Cicada rosae*. Since that time this insect has been placed in several genera by various writers in Europe and North America. It was first listed by Burmeister in 1835 as *Typhlocyba rosae* Linn., and under this name it has been commonly known in



THE ROSE LEAFHOPPER (EMPOA ROSAE).

A, Typical injury to apple leaf caused by the rose leafhopper; *B*, injury to currant leaf.



THE ROSE LEAFHOPPER.

A, Front view of head of male; *B*, overwintering eggs under bark of apple twig; *C*, adult with wings spread; *D*, adult with larva of dryinid parasite protruding from the body; *E*, *Anagrus armatus nigriventris*, parasite of winter egg.

entomological literature. The genus Empoa was erected by Fitch (22, p. 63) in 1851, and in 1889 Weed (25, p. 155) transferred *rosae* from Typhlocyba to Empoa. In recent years *rosae*, with a few exceptions, has been referred to under the genus Typhlocyba, owing to the persistant ignoring of Empoa Fitch.

This insect has been known as a pest of cultivated roses in several European countries for more than a hundred years. The first account of the rose leafhopper in this country was published by Harris (23, p. 199) in 1852, when he described it as *Tettigonia rosae*. Although brief mention has been frequently made of this hopper since Harris's time, the first record of it as an enemy of apple was made by Parrott (26) in 1909. Wilson and Childs (27) in 1915 were the first authors to treat of this insect at any length. They made a study of the rose leafhopper as a fruit pest in Oregon, giving the life history, habits, destructiveness, and remedial measures. Brittain (28), also in 1915, discussed this species as an enemy of apple in Nova Scotia.

SYNONYMY.

Empoa rosae (Linn.).

Cicada rosae Linn. Syst. Nat., ed. 10, v. 1, 1758, p. 439.
Typhlocyba rosae Burm. Handb. d. Ent., 2, 1835, p. 107.
Cicadula rosae Zett. Ins. Lap., 1840, p. 299.
Typhlocyba pteridis Dahlb. Kongl. Vet.-Akad. Handl., 1850, p. 179.
Tettigonia rosae Harr. Ins. Inj. to Veg., 2nd ed., 1852, p. 199.
Eupteryx rosae Marsh. Ent. Mo. Mag., v. 3, 1866–1867, p. 246.
Typhlocyba lactea Dougl. Ent. Mo. Mag., v. 12, 1875, p. 77.
Anomia rosae Fieber. Rev. d'Ent., v. 3, 1884, p. 124.
Empoa rosae Weed. Amer. Gard., July, 1889, p. 257.

ORIGIN AND DISTRIBUTION.

The rose leafhopper is undoubtedly of European origin, as it was known to Linnaeus more than a century before it was first recorded in this country. It probably was introduced from abroad in the egg stage on rose or apple stock.

It is distributed generally throughout the United States and has been taken from States forming the extreme northern, southern, eastern, and western limits of the country. It is apparently most abundant in the Northern States, particularly in the Pacific Northwest. In Canada, this insect has been reported from Nova Scotia, Ontario Province, and from British Columbia. In Europe it has been recorded from several localities in England, France, and Germany.

FOOD PLANTS.

This insect, although primarily a pest of rose and apple, is a rather general feeder. At West Chester, Pa., it has been taken feeding upon rose, apple, pear, peach, plum, cherry, quince, currant, gooseberry, raspberry, blackberry, grape, Crataegus, elm, oak, and cottonwood (*Platanus deltoides*). In addition, Wilson and Childs list strawberry, logan blackberry, and prune from Oregon. It is likely that this leafhopper will feed on the foliage of most plants belonging to the family Rosaceae.

CHARACTER OF INJURY.

The nymphs and adults of *Empoa rosae* confine their feeding entirely to the lower leaves of apple trees in the nursery. They congregate on the lower surfaces of the foliage and suck the plant juices by puncturing the leaf tissue with their tiny beaks. The first indication of the injury is the mottling of the leaves with yellowish or whitish spots at the points where the punctures were made. (See Pl. IV.) When the leaves become heavily infested they turn yellow, dry up, and drop to the ground prematurely. The foliage is never curled by this species, nor is the terminal growth checked, as in the case of injury by *Empoasca mali*.

A second type of injury is produced by the egg punctures made by the females in the fall during the oviposition period. The eggs are deposited under the bark of young apple trees, several hundred eggs often being placed in a single twig.

The injury produced by the rose leafhopper to apple nursery stock is of little importance, however, when compared with that caused by the more destructive apple leafhopper.

DESCRIPTION OF STAGES.

EGG.

Pl. V, B.

The winter egg is elongate oval, slightly crescentic in form, almost circular in cross section, and blunt at both ends. It is almost transparent at first, but when ready to hatch it changes to a milky white color, while the red eyes of the young nymph are visible through the smooth chorion.

Average length of 16 eggs 0.65 mm., width 0.19 mm.

NYMPH.

First instar.—Color of first-instar nymph pale white changing to light yellow after feeding. Eyes dull red. Small spines present on the dorsal side of the head, thorax, and abdomen; the latter with four spines to each segment arranged in two longitudinal rows on each side. Posterior margin of metathorax blunt. First two segments of antennæ pale, remainder dusky. Average length of 16 specimens 0.98 mm.

Second instar.—General color creamy white to light yellow. Eyes lose some of their red color, becoming lighter. Wing pads begin to appear as lateral buds. Posterior margin of metathorax sharp in outline. First two segments of antennae yellow, remainder dusky. Average length of 16 specimens 1.27 mm.

Third instar.—General color light yellow. Eyes dull white. Body more robust than in first two stages. Wing pads extending to hind margin of the first abdominal segment. Spines darker and more prominent. Average length of 16 specimens 1.55 mm.

Fourth instar.—General color light yellow. Eyes almost pearl white with a brown central spot underneath. Wing pads extending to hind margin of the second abdominal segment. Spines very distinct. Average length of 16 specimens 2.03 mm.

Fifth instar.—General color as in previous stage. Eyes almost pearl white. Wing pads extending nearly to the hind margin of the fourth abdominal segment. Broader than in previous stage. Average length of 16 specimens 2.85 mm.

THE ADULT.

Pl. V, A, C.

General color of adult creamy white to light yellow. Head rather pointed, pale yellow; face of male with a tint of orange color in the form of a central longitudinal stripe with several transverse radiating stripes; genæ pale, narrow, and almost as long as clypeus; loræ very narrow, sunken beneath the compound eyes. Vertex pale yellow with two semitransparent spots just above the ocelli, a faint median longitudinal semitransparent line extending from the hind margin half-way to the front margin, and a semitransparent line bordering each eye. Two ocelli present, situated on the frontal margin of the vertex, marked by two white spots with a dark center, distance apart twice that from the eye to the ocellus; eyes pearl white with a darkened center, ashen-gray after death. Pronotum light yellow with a semitransparent area in the center; mesonotum semitransparent with a large trapezoidal creamy area extending from the front to the hind margins, wider behind; a small cream colored area anteriorly on each side; scutellum cream-colored, sometimes with a semitransparent area caudad. Elytra transparent. First two segments of antennæ pale, flagellum dusky. Legs pale, tarsi dusky at tips. Sexual appendages slightly ciliated in female only. Average length of 12 specimens 3.00 mm.

LIFE HISTORY AND HABITS.

THE EGG.

Part of the rearing work in the life history of the rose leafhopper was conducted during the spring of 1915, the work being completed during the season of 1916. In obtaining data on the biology of this insect the same methods as devised for the study of the apple leafhopper were used.

Winter egg.—This leafhopper hibernates in the egg stage, winter eggs being deposited in the fall during the period extending from the last week in September to November 1. They are laid almost entirely under the bark of apple trees and rose bushes, though a few have been found in pear, quince, cherry, plum, currant, and Crataegus. The eggs are deposited singly, usually lying in a longitudinal position just under the epidermis, and they are placed in a distinct blister or pouch which measures 0.7 to 0.8 mm. in length. They are easily located by looking on the bark for the raised blister, which, as a rule, is slightly crescentic in outline. Winter eggs have been found in the bark of nursery apple trees from one to four years old; they are found in greatest numbers on the first year's growth of two-year trees. The favorite location for oviposition seems to be around the bases of the lowest limbs or on the trunk just below the first branches.

Summer eggs.—Summer eggs are laid by first-brood adults during July in the veins of the lower leaves.

THE NYMPH.

The nymphs of this species differ from those of *Empoasca mali* by their paler color, by their smaller size, and by the fact that they confine their activities entirely to the lower leaves of the trees. Though very active they are not quite as quick in their movements as the nymphs of the apple leafhopper.

As the young nymphs emerge from the eggs in the bark they make their way to the nearest leaves, where they immediately settle down to feed. In the vicinity of West Chester, Pa., the first nymphs of the season emerge about May 1, and by May 15 practically all the winter eggs have hatched. Generally speaking, the nymphs of this species are from three to four weeks old before the first nymphs of *Empoasca mali* appear on the terminal leaves.

THE ADULT.

Nymphs of the first brood transform to adults during the first two weeks in June and these adults feed on the foliage for several weeks before mating. Oviposition extends over a period of about two weeks during late June and early July, most of the first-brood adults dying by the end of July.

Second-brood adults begin to appear during the first week in August, and they remain on the trees until death, which occurs by November 1, after the winter eggs have been deposited. A few adults have been noticed on the trees as late as November 25. No rose leafhoppers, either in confinement or in the field, were observed to hibernate in the adult stage.

FIRST GENERATION.

FIRST BROOD OF EGGS.

The length of the incubation period of the first-brood eggs (i. e., the winter eggs) is 6 to 7 months. Eggs deposited during October hatch by the middle of May of the following year at the latest.

FIRST BROOD OF NYMPHS.

Nymphs newly hatched from winter eggs were confined in individual cork cages on uninfested leaves. The average length of the entire nymphal period, as indicated in Table XIV, was 33.4 days; the maximum, 36 days; the minimum, 30 days.

TABLE XIV.—*Length of nymphal stages of the first brood of the rose leafhopper on nursery apple trees at West Chester, Pa., 1915.*

First brood, May and June.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average mean temperature for nymphal period.
1915.	1915.	*Days.*	1915.	*Days.*	1915.	*Days.*	1915.	*Days.*	1915.	*Days.*	*Days.*	°*F.*
May 6	May 11	5	May 14	3	May 21	7	May 28	7	June 7	10	32	67.19
May 7	May 13	6	May 17	4	May 24	7	May 30	6	June 8	9	32	67.33
Do...	May 14	7	May 21	7	May 29	8	June 4	6	June 12	8	36	68.16
Do...	...do....	7	May 22	8	May 28	6	June 2	5	June 10	8	34	67.47
Do...	May 15	8	...do.....	7	...do.....	6	June 3	6	June 11	8	35	67.79
Do...	May 12	5	May 20	8	May 26	6	...do.....	8	June 9	6	33	67.44
Do...	May 16	9	May 23	7	May 29	6	June 5	7	June 12	7	36	68.16
Do...	May 15	8	...do.....	8	May 30	7	June 4	5	June 11	7	35	67.79
May 8	May 13	5	May 21	8	May 27	6	June 3	7	...do...	8	34	67.70
May 11	May 16	5	...do.....	5	...do.....	6	...do.....	7	June 10	7	30	67.85
Do...	May 17	6	May 22	5	May 28	6	...do.....	6	June 11	8	31	68.29
Average.......		6.4	....	6.3	....	6.4	....	6.3	....	7.8	33.4	67.74

FIRST BROOD OF ADULTS.

No attempt was made to obtain definite data on the longevity of first-brood adults. Ninety adults, however, were confined in a Riley cage on a young apple tree on May 31, 1916, and the last leafhoppers died on August 1; by this date many of the second-brood nymphs had appeared. Thus, the length of life of the adults of this brood is approximately two months.

SECOND GENERATION.

SECOND BROOD OF EGGS.

Length of incubation period.—An approximation of the length of the egg stage of second-brood eggs (i. e., the summer eggs) is shown in Table XV. The average length of the period was 25 days; the maximum, 27 days; the minimum, 23 days.

TABLE XV.—*Length of incubation period of summer eggs deposited by first-brood females of the rose leafhopper, West Chester, Pa., 1916.*

Four pairs of adults placed in confinement on apple tree July 28, 1916, 4 p. m.; adults removed July 29, 4 p. m.

Date of removal of newly hatched nymphs.	Number of nymphs removed.	Incubation period.	Date of removal of newly hatched nymphs.	Number of nymphs removed.	Incubation period.
1916.		*Days.*	1916.		*Days.*
Aug. 21	0	....	Aug. 25	0	....
Aug. 22	9	23–25	Aug. 26	0	....
Aug. 23	2	24–26	Aug. 27	0	....
Aug. 24	2	25–27	Aug. 28	0	....

SECOND BROOD OF NYMPHS.

Length of stages.—In Table XVI the length of the stages and of the entire nymphal period is recorded. The average length of the nymphal period was 17.7 days; the maximum, 19 days; the minimum, 16 days. It will be noted that the length of the nymphal period of the second brood was much shorter and that the corresponding temperatures were much higher than in the case of the first-brood nymphs.

TABLE XVI.—*Length of nymphal stages of second brood of the rose leafhopper on nursery apple trees at West Chester, Pa., 1916.*

Second brood, July and August.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average mean temperature for nymphal period.
1916.	1916.	*Days.*	1916.	*Days.*	1916.	*Days.*	1916.	*Days.*	1916.	*Days.*	*Days.*	°*F.*
July 21	July 25	4	July 28	3	July 31	3	Aug. 3	3	Aug. 7	4	17	79.72
July 24	July 28	4	July 31	3	Aug. 4	4	Aug. 6	2	Aug. 10	4	17	80.13
July 25	July 27	2	...do.....	4	Aug. 3	3	...do.....	3	...do....	4	16	80.38
Do...	July 28	3	Aug. 1	4	Aug. 5	4	Aug. 7	2	Aug. 12	5	18	80.55
Do...	July 31	6	Aug. 3	3	...do.....	2	Aug. 8	3	...do....	4	18	80.55
July 28	...do....	3	Aug. 4	4	Aug. 6	2	Aug. 9	3	Aug. 15	6	18	79.84
Do...	Aug. 1	4	...do.....	3	...do.....	2	...do.....	3	...do....	6	18	79.84
Do...	...do....	4	...do.....	3	...do.....	2	Aug. 10	4	Aug. 16	6	19	79.70
Do...	...do....	4	Aug. 5	4	Aug. 8	3	Aug. 12	4	Aug. 15	3	18	79.84
July 30	Aug. 2	3	Aug. 6	4	...do.....	2	...do.....	4	Aug. 17	5	18	80.26
Do...	Aug. 4	5	...do.....	2	Aug. 10	4	Aug. 15	5	Aug. 18	3	19	80.40
Do...	Aug. 2	3	...do.....	4	Aug. 9	3	Aug. 13	4	...do....	5	19	80.40
July 31	Aug. 5	5	Aug. 9	4	Aug. 12	3	Aug. 16	4	Aug. 19	3	19	80.75
Do...	...do....	5	Aug. 8	3	...do.....	4	Aug. 15	3	...do....	4	19	80.75
Aug. 3	Aug. 6	3	Aug. 10	4	Aug. 13	3	Aug. 16	3	Aug. 20	4	17	80.94
Aug. 4	Aug. 7	3	Aug. 9	2	...do.....	4	Aug. 17	4	Aug. 21	4	17	81.38
Do...	Aug. 6	2	Aug. 11	5	Aug. 15	4	Aug. 18	3	...do....	3	17	81.38
Do...	Aug. 8	4	Aug. 12	4	...do.....	3	Aug. 17	2	Aug. 20	3	16	81.23
Do...	...do....	4	Aug. 13	5	Aug. 16	3	Aug. 19	3	Aug. 22	3	18	81.68
Aug. 5	...do....	3	Aug. 11	3	Aug. 15	4	Aug. 17	2	Aug. 21	4	16	81.29
Average.......		3.7	....	3.5	....	3.1	....	3.2	....	4.1	17.7	80.50

SECOND BROOD OF ADULTS.

Extent of reproduction.—Pairs of second-brood adults were confined in arc-light globe cages to determine the number of winter eggs deposited per female in the bark of apple. The data in Table XVII were obtained in the fall of 1915, and that in Table XVIII in 1916. The hoppers were allowed to remain on the trees until death. The average number of eggs deposited per female during the two experiments was 15.5 and 16, respectively.

Attempt to rear a third brood of nymphs.—A globe-cage experiment was conducted to determine whether second-brood adults would produce a third brood of nymphs. Ten pairs were confined on August 7 in two cages and examined at intervals until October 1. In no case did any third-brood nymphs develop, only winter eggs being deposited by the females.

TABLE XVII.—*Number of winter eggs deposited in bark of apple trees by second-brood adults in confinement, West Chester, Pa., 1915.*

Cage.	Date of confinement.	Number of pairs confined.	Date of examination.	Number of eggs present.
	1915.		1915.	
1	Sept. 26	6	Nov. 25	98
2	Oct. 9	5	...do	78
	Total			176
	Average per female			16

TABLE XVIII.—*Number of winter eggs deposited in bark of apple trees by second-brood adults in confinement, West Chester, Pa., 1916.*

Cage.	Date of confinement.	Number of pairs confined.	Date of examination.	Number of eggs present.
	1916.		1916.	
1	Aug. 7	6	Nov. 7	104
2	Sept. 6	9	Nov. 8	129
	Total			233
	Average per female			15.5

In Table XIX the daily temperature is given for the period of seasonal activity, 1916.

TABLE XIX.—*Daily maximum, minimum, and average temperature taken at West Chester, Pa., from July 21 to Oct. 31, 1916.*

Day of month.	July.			August.			September.			October.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
1916.	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
1				85	74	79.5	84	78	81	53	45	49
2				80	70	75	81	76	78.5	65	50	57.5
3				78	74	76	72	66	69	70	53	61.5
4				88	78	83	78	70	74	65	61	63
5				88	77	82.5	83	72	77.5	75	59	67
6				92	80	86	84	76	80	73	65	69
7				91	82	86.5	86	78	82	70	62	66
8				92	75	83.5	88	74	81	77	60	68.5
9				85	76	80.5	76	68	72	82	70	76
10				82	68	75	74	66	70	53	43	48
11				86	78	82	72	60	66	62	50	56
12				86	78	82	76	61	68.5	70	58	64
13				74	70	72	81	65	73	56	54	55
14				78	72	75	84	72	78	60	52	56
15				80	74	77	72	64	68	60	45	52.5
16				80	74	77	66	56	61	62	59	60.5
17				90	80	85	70	62	66	68	60	64
18				86	80	83	68	60	64	58	44	51
19				90	82	86	62	51	56.5	67	56	61.5
20				88	82	85	72	57	64.5	80	68	74
21	80	72	76	93	75	84	72	56	64	57	49	53
22	81	70	75.5	92	82	87	75	64	69.5	54	45	49.5
23	84	76	80	92	82	87	76	68	72	56	44	50
24	78	74	76	79	69	74	68	55	61.5	61	48	54.5
25	76	74	75	84	66	75	66	57	61.5	64	46	55
26	82	78	80	84	75	79.5	72	57	64.5	56	48	52
27	90	75	82.5	86	74	80	79	66	72.5	58	49	53.5
28	80	74	77	70	64	67	82	70	76	56	49	52.5
29	80	74	77	74	64	69	72	56	64	61	46	53.5
30	84	74	79	80	66	73	59	46	52.5	67	50	58.5
31	92	85	88.5	82	65	73.5				62	50	56

SUMMARY OF SEASONAL HISTORY.

There are two generations of the rose leafhopper annually at West Chester, Pa. This insect hibernates in the egg stage, the eggs being deposited under the bark of the host plants. On apple stock in the nursery the winter eggs hatch from May 1 to May 15, and the newly hatched nymphs immediately attack the lower leaves of the trees. The feeding period of the first brood of nymphs covers approximately one month. The first adults of the season appear by the end of May. The latter feed for several weeks before mating and depositing the second brood of eggs in the foliage. The length of the life of the first-brood adults is about two months, most of them having disappeared by the first week in August.

The length of the incubation period of the second-brood eggs is about 25 days, the first eggs hatching about July 20. Due to the higher temperatures, the length of the nymphal period of this brood is comparatively shorter than that of the spring brood of nymphs. Second-brood nymphs, on an average, attain the adult stage in 17 days. By the latter part of August, practically all the nymphs have transformed to adults. The adults feed for about a month before mating, which takes place during the latter part of September. Females deposit the winter eggs throughout the month of October, soon after which they die. The last adults of the season were found on the trees on November 25.

NATURAL ENEMIES.

The most efficient enemies of the rose leafhopper are two species of hymenopterous egg parasites belonging to the superfamily Proctotrypoidea. Thesepar asites were determined by Mr. A. A. Girault, of the Bureau of Entomology, as *Anagrus epos* Girault and *Anagrus armatus* Ashm. var. *nigriventris* Girault. (See Pl. V, E.) These two parasites were reared from the winter eggs only, and they emerged both in the fall and in the spring. In the fall they emerged from October 15 to November 1, while in the spring they were reared in abundance about one or two weeks after the hatching of the winter eggs.

These egg parasites are a valuable factor in reducing the destructive numbers of the leafhopper. At West Chester, Pa., from 65 to 70 per cent of the winter eggs were parasitized during 1916. Both of these species evidently are widely distributed, as they have been reared from the eggs in apple twigs from Hagerstown, Md., Winchester, Va., and Roswell, N. Mex.

Adults of this leafhopper are parasitized quite heavily by a species of the family Dryinidae. A rose leafhopper parasitized by a dryinid (Pl. V, D) is readily recognized by the distorted appearance of one of its wings under which the parasitic larva is noticed protruding from the abdomen. Numerous parasitized leafhoppers were collected but no adult parasites were reared successfully.

A. Giard (24), in 1889, reported the dryinid *Aphelopus melaleucus* Dalm. and the pipunculid *Ateleneura spuria* Meig. as parasites of *Typhlocyba rosae* in France.

Among the predacious enemies of this insect, mites, spiders, and coccinellid and syrphid larvæ have been noted feeding on the nymphs to a limited extent.

Wilson and Childs (27), in 1915, recorded the larva of a green lacewing, *Chrysopa* sp., as preying on young nymphs in Oregon. The same authors list a dragonfly and a scatophagidfly as predacious enemies of adults.

REMEDIAL MEASURES.

The apple leafhopper, *Empoasca mali*, is one of the most difficult of all leafhoppers to combat successfully, especially because of the wide range of its food plants. In nurseries, however, this species confines its attack chiefly to the foliage of the apple, and if the hoppers can be reduced in sufficient numbers on this plant the danger of infestation from other host plants will be very small.

Little actual work has been done in dealing with the remedial measures to be used against this pest. One of the most frequently recommended methods which many writers have suggested as a means of controlling this leafhopper in nurseries is the use of sticky shields to catch the winged adults as they are jarred from the trees along the nursery row. The use of such a device has never proved satisfactory and it is impracticable when employed on a large scale.

Spraying with contact insecticides against the apple leafhopper has been generally advised. Weiss (19) suggested spraying with 1 pint of "black-leaf 40" to 100 gallons of Pyrox. But in general the recommendations have been so indefinite and vague that little value can be attached to them. In order to clear up the confusion which has existed in regard to the treatment for this insect, spraying experiments, based on the life-history studies, were carried out.

SPRAYING FOR THE FIRST BROOD.

Spraying experiments against the nymphs were conducted in the nursery of Hoopes Bros. & Thomas Co. at West Chester, Pa. Tests on a small scale were made, the spray being applied with a compressed-air sprayer and an angle nozzle at a pressure of 60 pounds. Larger plats were sprayed with a machine owned by the nursery which consisted of a double-acting hand pump capable of 100 pounds pressure and a 50-gallon galvanized tank set on a truck narrow enough to allow it to pass between two rows of trees. "Set nozzles" on an arrangement of pipes at the rear of this outfit were used, the nozzles being so placed that it was possible to spray the undersides of the leaves of two rows of trees from both sides. It was necessary to use eight nozzles on this machine and consequently the pressure was greatly reduced.

Table XX indicates the results obtained with the compressed-air sprayer against the first-brood nymphs:

TABLE XX.—*Spraying experiments against the first-brood nymphs of the apple leaf-hopper, West Chester, Pa., 1916.*

Plat No.	Spray material.	Strength.	Date of application.	Number of trees treated.	Nymphs killed.
					Per cent.
1	40 per cent nicotin sulphate and fish-oil soap	1–1,000 2–50	June 12	300	99
2	40 per cent nicotin sulphate and fish-oil soap	1–1,400 2–50	...do....	300	98
3	40 per cent nicotin sulphate	1–1,400	...do....	300	94
4	40 per cent nicotin sulphate lime-sulphur solution	1–1,500 1½–50	...do....	300	99
5	Check; unsprayed	....	....	....	0

It will be noted that good results were obtained on all plats of this experiment from the use of 40 per cent nicotin sulphate, though slightly better control was obtained when soap was added as a spreader.

The hand-power outfit with "set nozzles" was used in an experiment on several thousand 2-year-old trees which were heavily infested with first-brood nymphs.

The results are shown in Table XXIV.

TABLE XXI.—*Spraying experiments against the first-brood nymphs of the apple leaf-hopper, West Chester, Pa., 1916.*

Plat No.	Spray material.	Strength.	Date of application.	Number trees treated.	Nymphs killed.
					Per cent.
1	40 per cent nicotin sulphate	1–1,400	June 15	4,000	92
2	.....do	1–1,500	...do.....	10,000	91
3	.....do	1–1,600	...do.....	4,000	89
4	40 per cent nicotin sulphate and fish-oil soap	1–1,500 2–50	June 16	13,000	97
5	Fish-oil soap	1–8	....do....	4,000	50
6	Kerosene emulsion	5 per cent	....do....	4,000	45
7	Check, unsprayed	....	....	....	0

As will be noted, the best results in Table XXI were obtained on plat 4 where 40 per cent nicotin sulphate at a strength of 1–1,500 was combined with soap. The nicotin solution when used alone proved a little less effective than when the soap was added to the mixture as shown in plats 1, 2, and 3. A potash fish-oil soap solution at a strength of 1 pound of soap to 8 gallons of water (plat 5) gave poor results and was but little more valuable than a 5 per cent kerosene emulsion which was tried on plat 6.

During the spray application with "set nozzles" it was noted that the terminals of an occasional tree were missed by the spray. One reason for this was that the machine was top heavy and easily jolted when passing over a rough or stony place, and this resulted in the spray material being sent over the top of a tree. Furthermore, a few trees would outgrow the remainder of the trees in a row, so the spray material from the "set nozzles" would not reach the terminals of such trees. Nevertheless, sufficiently good results were obtained with the "set nozzles" to warrant their use.

TREATMENT FOR THE SECOND BROOD.

An attempt was made to destroy the second-brood nymphs by spraying and dipping upon trees which had received no treatment against the first brood. On the date of this experiment, July 18, the terminal leaves were so badly curled that the nymphs were well protected from the action of the spray. Four plats of about 700 trees were sprayed with a compressed-air sprayer, using 40 per cent nicotin sulphate at various strengths from 1–800 to 1–1,500 with soap added. The counts showed that only 2 per cent of the nymphs were killed on the best plats.

The dipping work was done with large shallow pans specially constructed for dipping leafhoppers and aphids on young nursery trees. The tops of the trees were thoroughly immersed in the pans of spray material. The same number of plats and the same insecticides that were used in the spray treatment above were tried in the dipping experiments. The results obtained by dipping were about the same as the spraying results, less than 2 per cent of the nymphs being killed.

Since such poor results were secured from spraying experiments against the second brood no effort was made to spray the third-brood nymphs, for at the time of the presence of the latter on unsprayed trees the terminals are even further curled and inaccessible to a spray liquid.

METHODS AND TIME OF APPLICATION.

Attempts to control the winged adults of leafhoppers by spraying have always proved futile because of the agility of movement of the full-grown insects and because of their immunity to the action of a spray liquid at this stage. This has been demonstrated by previous investigators in the case of the apple leafhopper as well as in the case of other leafhoppers of economic importance.

A spray treatment to be effective must be applied when the insects are in the nymphal stages. The proper time to spray against the apple leafhopper is at the time when a large number of the first-brood nymphs have attained the third stage of development. For the seasons of 1915 and 1916 at West Chester, Pa., this date was between June 10 and June 20. It is not safe to delay the application until the end of the nymphal period, since by that time the insects will have produced sufficient injury to cause the tender terminal leaves to curl, and the result is that the nymphs on the curled leaves will be protected against the spray.

The nymphs feed on the undersides of the terminal leaves during the entire nymphal period, so the spray material must be directed in such a manner as to wet the underside of the leaves thoroughly. Special care must be taken to see that the foliage of the upper half of the trees and especially the terminals are well sprayed. If a machine with "set nozzles" is used, the lower nozzles should be placed at an angle that will insure a thorough spraying of the lower surfaces of the leaves.

TREATMENT FOR THE ROSE LEAFHOPPER.

The injury caused by the rose leafhopper on nursery apple trees is seldom serious enough to warrant a special spray application. This species confines its attack to the undersides of the leaves of the lower half of the trees and the injury is characterized by mottled white or yellowish spots on the foliage. As a result of continued feeding some defoliation takes place which reduces the vitality of the trees slightly.

Whenever necessary, this species can be controlled by one spray application of a tobacco insecticide against the first-brood nymphs. A spraying of ¼ pint of 40 per cent nicotin sulphate to each 50 gallons of water with the addition of 2 pounds of soap, made at the time when the maximum number of nymphs are present on the foliage, will give satisfactory results. The most effective time to make this application is when the greatest number of nymphs have reached the third stage, which is three to four weeks earlier than the date for the spraying against the first-brood nymphs of the apple leafhopper. For southeastern Pennsylvania the correct time for spraying the rose leafhopper during the seasons of 1915 and 1916 was from May 15 to May 25.

RECOMMENDATIONS.

The apple leafhopper can be controlled by spraying against the first-brood nymphs with a tobacco insecticide. A 40-per cent nicotin sulphate solution at the rate of 1–1,500 to which 2 pounds of soap is added to each 50 gallons will so reduce their numbers that injury to the growth of the trees by the later broods will not be serious. When it is desirable to use lime-sulphur solution with the tobacco insecticide, soap must be omitted to prevent burning. The spray should be directed upward so as to wet the underside of the leaves, and particular attention should be paid to wetting every terminal leaf thoroughly. The application should be made when the majority of the nymphs are in the third stage, which occurs about three weeks after the first nymphs are found in the terminal leaves.

The rose leafhopper is far less injurious to the foliage of nursery apple stock than the apple leafhopper. Should the infestation by rose leafhoppers be heavy enough to justify spraying, the same remedial treatment recommended for the apple leafhopper can be used, except that the application should be made three or four weeks earlier than the one for the latter insect.

SUMMARY.

The apple leafhopper, *Empoasca mali*, causes serious injury to apple nursery stock by extracting the plant juices from the terminal leaves; as a consequence the leaves curl, become undersized, and fail to function normally, thereby retarding the growth of the trees. The injury is produced by the feeding of both nymphs and adults. In southern Pennsylvania this species is three-brooded and hibernates only in the adult stage. Eggs are laid within the leaf tissue on the underside of the leaves. This leafhopper is widely distributed over the United States and attacks a great variety of host plants.

In literature the above species has been confused with another leafhopper which attacks the foliage of nursery apple trees, namely, the rose leafhopper, *Empoa rosae*. The latter insect is two-brooded and winter is passed in the egg stage. Winter eggs are deposited under the bark of apple trees. These eggs hatch about a month earlier in the spring than eggs deposited by overwintered females of the former species.

The rose leafhopper may be distinguished from the apple leafhopper by its lighter color and by the absence of the six or eight white spots present on the frontal margin of the pronotum of the latter species. Differentiation between the nymphs of the two species is more difficult. The distinct types of injury produced by the two insects, however, is a ready means of distinguishing them. The rose leafhopper feeds on the lower leaves and produces white or yellow spots on them while the other species attacks the terminal leaves, curls them, and stunts the growth of the trees.

Parasites seem to play a far more important rôle in reducing the numbers of the rose leafhopper than they do in reducing the numbers of the more injurious apple leafhopper. Larvæ of dryinid parasites are quite common on the adults of the former while only rarely have they been found attacking the latter. *Anagrus epos* Girault and *Anagrus armatus* Ashm. var. *nigriventris* Girault, parasites of the winter egg of the rose leafhopper, help considerably in checking the numbers of this species. No parasites have been reared from eggs of the apple leafhopper.

A single spraying with 40 per cent nicotin sulphate at the rate of 1–1,500 combined with soap will so materially check an infestation by the apple leafhopper when applied against the first-brood nymphs that injury caused later by those that escape will be of little consequence. The same treatment made three or four weeks earlier is effective against the rose leafhopper, though this species is seldom injurious enough to justify a special application.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 806

Joint Contribution from the Bureau of Plant Industry, WM. A. TAYLOR, Chief, and the Bureau of Crop Estimates, L. M. ESTABROOK, Chief

Washington, D. C. ▼ December 8, 1919

PEACHES: PRODUCTION ESTIMATES AND IMPORTANT COMMERCIAL DISTRICTS AND VARIETIES.

By H. P. Gould, *Bureau of Plant Industry*, and Frank Andrews, *Bureau of Crop Estimates.*

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RELATIVE IMPORTANCE AND EXTENT OF THE PEACH INDUSTRY.

The peach, though far below the apple,[1] which greatly exceeds any other fruit in both acreage and crop value, is second with respect to these two standards of comparison. This is shown clearly in figure 1, which is based on the Thirteenth Census. While the last decade has witnessed some changes, it is doubtful whether those changes have affected materially the relative positions of the more important fruits. Nectarines are grouped with peaches in figure 1, but the total production of nectarines is so small as to be a negligible factor.

The geographical distribution of peach trees is shown in figures 2 and 3, both of which are based on the Thirteenth Census. The census data, which show the distribution on a tree basis, are reduced in these maps to an acre basis for convenience of expression. As in figure 1, nectarines, which are grouped with peaches, are of such small importance as to be without substantial effect on the peach data.

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[1] See Gould, H. P., and Andrews, Frank, "Apples: Production Estimates and Important Commercial Districts and Varieties," Bul. 485, Dept. of Agr. 48 pp., 16 figs. 1917. This bulletin is obtained only from the Superintendent of Documents, Government Printing Office, at a cost of 10 cents.

ESTIMATED PRODUCTION OF PEACHES.

The estimates of the annual production of peaches for the years 1900 to 1919, inclusive, appear in Table I.

The estimates for the years 1900 to 1908 are based on the census report for the crop of 1899, while for the years 1910 to 1919, inclusive, they are based on the census figures for the crop of 1909.

The variation in the size of the peach crop from year to year is shown in figure 4. While all census data as well as estimates based on those data are expressed in terms of the total crop, including both home consumption and the commercial crop, the annual variation indicated suggests also the fluctuating character of that portion of the crop which enters into commerce.

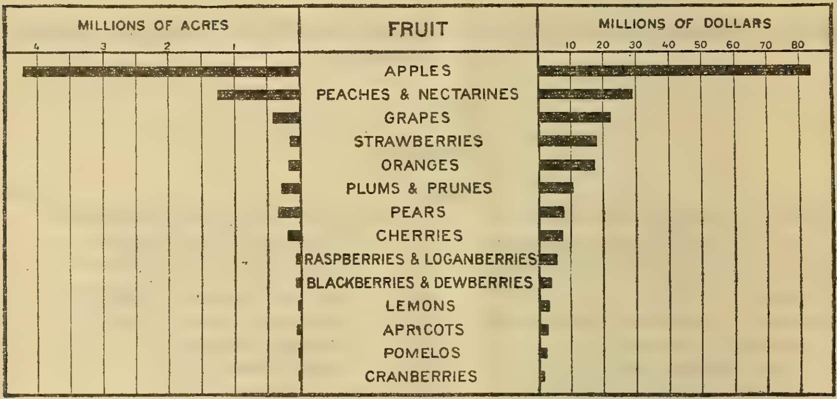
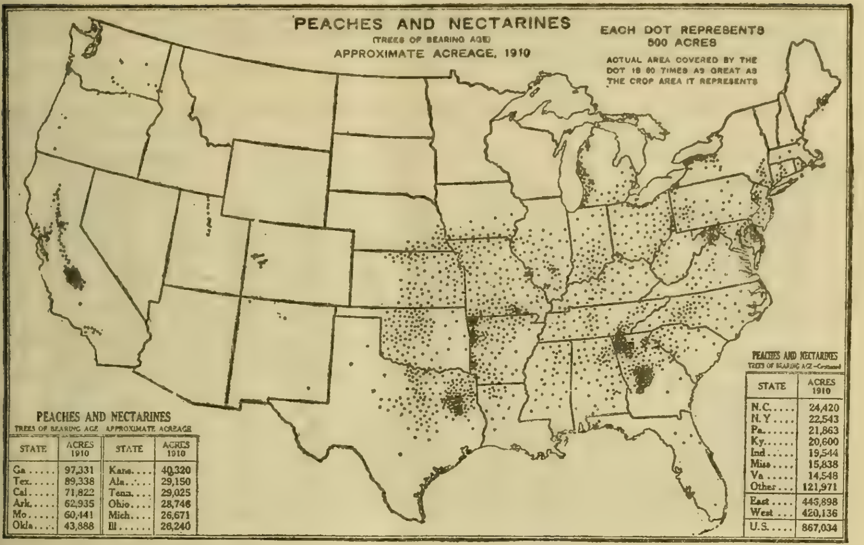


FIG. 1.—Diagram showing the relative importance, acreage, and crop values of the principal fruits of the United States for the year 1909, based on the report of the Thirteenth Census. (From the Yearbook of the Department of Agriculture for 1915.)

Climatic conditions doubtless are the most potent causes of large annual variation in the size of the crop. Most important of these are adverse winter temperatures and the occurrence of spring frosts during the blossoming period. In addition, warm periods during the winter often cause the fruit buds to start enough to become tender. In this condition they are likely to be killed later, even by temperatures that are not unseasonable. On the other hand, the effect of a frost during the blossoming period is not always in proportion to its severity, but depends to some extent upon the strength and vigor of the blossoms themselves.


PEACHES AND NECTARINES
(TREES OF BEARING AGE)
APPROXIMATE ACREAGE, 1910
EACH DOT REPRESENTS 500 ACRES
ACTUAL AREA COVERED BY THE DOT IS 60 TIMES AS GREAT AS THE CROP AREA IT REPRESENTS

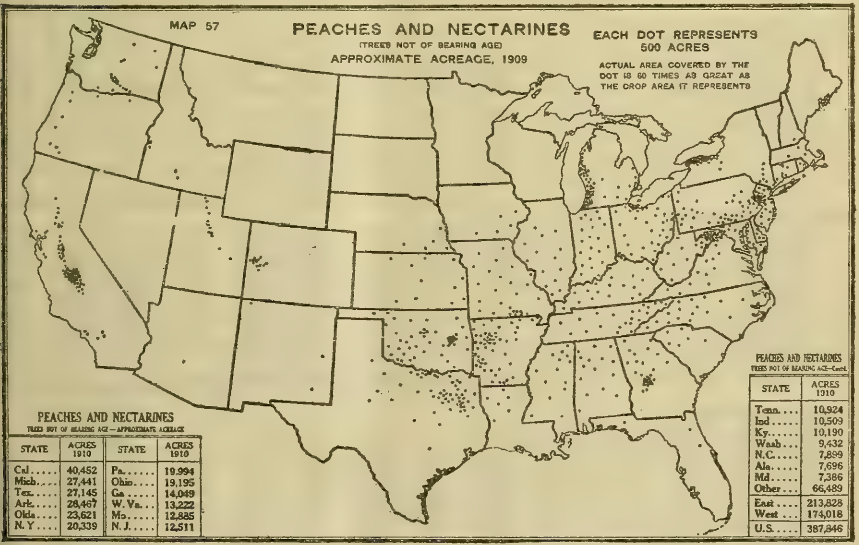
PEACHES AND NECTARINES
TREES OF BEARING AGE APPROXIMATE ACREAGE

STATE	ACRES 1910	STATE	ACRES 1910
Ga......	97,331	Kans....	40,320
Tex.....	89,338	Ala.....	29,150
Cal.....	71,822	Tenn....	29,025
Ark.....	62,935	Ohio....	28,746
Mo......	60,441	Mich....	26,671
Okla....	43,888	Ill......	26,240

PEACHES AND NECTARINES
TREES OF BEARING AGE—Continued

STATE	ACRES 1910
N.C.....	24,420
N.Y.....	22,543
Pa......	21,863
Ky......	20,600
Ind......	19,544
Miss.....	15,838
Va......	14,548
Other...	121,971
East....	445,898
West ...	420,136
U.S.....	867,034

FIG. 2.—Map of the United States, showing the distribution and approximate acreage of peach trees of bearing age, based on the Thirteenth Census. Each dot represents 500 acres. The solid black areas indicate relatively great density of planting. (From the Yearbook of the Department of Agriculture for 1915.)


MAP 57
PEACHES AND NECTARINES
(TREES NOT OF BEARING AGE)
APPROXIMATE ACREAGE, 1909
EACH DOT REPRESENTS 500 ACRES
ACTUAL AREA COVERED BY THE DOT IS 60 TIMES AS GREAT AS THE CROP AREA IT REPRESENTS

PEACHES AND NECTARINES
TREES NOT OF BEARING AGE—APPROXIMATE ACREAGE

STATE	ACRES 1910	STATE	ACRES 1910
Cal......	40,452	Pa......	19,994
Mich.....	27,441	Ohio....	19,195
Tex.....	27,145	Ga......	14,049
Ark.....	28,467	W. Va...	13,222
Okla....	23,621	Mo......	12,885
N. Y....	20,339	N. J.....	12,511

PEACHES AND NECTARINES
TREES NOT OF BEARING AGE—Contd.

STATE	ACRES 1910
Tenn....	10,924
Ind......	10,509
Ky......	10,190
Wash...	9,432
N.C.....	7,899
Ala......	7,696
Md......	7,386
Other...	66,489
East....	213,828
West ...	174,018
U.S.....	387,846

FIG. 3.—Map of the United States, showing the distribution and approximate acreage of peach trees of nonbearing age, based on the Thirteenth Census. Each dot represents 500 acres. (From the Yearbook of the Department of Agriculture for 1915.)

TABLE I.—*Estimated production of peaches in the United States for the 21-year period, 1899 to 1919, inclusive.*

[Data in thousands of bushels (000 omitted). The figures for the years 1899 and 1909 are Census estimates. The figures for other years are interpretations of the percentage estimates by the Bureau of Crop Estimates, the Census figures being used as a basis.]

Group and State.	1899 (Census).	1900	1901	1902	1903	1904	1905	1906	1907	1908
North Atlantic States:										
Maine	2	2	2	2	2	2	2	2	2	2
New Hampshire	6	30	8	50	20	40	35	30	20	45
Vermont	1	1	1	1	1	1	1	1	1	1
Massachusetts	28	140	100	150	35	70	120	90	25	100
Rhode Island	6	8	13	14	2	5	12	13	5	12
Connecticut	62	140	280	230	50	110	240	200	50	220
New York	467	1,500	850	550	670	675	1,650	920	400	1,470
New Jersey	621	1,900	1,200	1,300	350	700	1,000	1,000	450	800
Pennsylvania	143	1,400	1,700	1,350	900	700	1,500	1,000	600	1,500
Total	1,336	5,121	4,154	3,647	2,030	2,303	4,560	3,256	1,553	4,150
South Atlantic States:										
Delaware	10	250	170	185	45	135	15	100	35	100
Maryland	172	1,900	1,300	1,140	600	950	600	850	250	750
Virginia	357	1,900	1,350	850	800	850	950	800	300	900
West Virginia	18	700	800	250	180	700	330	500	150	650
North Carolina	374	1,550	1,150	1,050	1,100	1,350	1,200	1,100	550	1,400
South Carolina	129	800	650	600	750	700	650	700	170	1,100
Georgia	260	5,000	3,340	3,370	2,100	5,000	3,025	3,720	1,125	5,020
Florida	92	190	160	190	110	180	140	150	80	160
Total	1,412	12,290	8,920	7,635	5,685	9,865	6,910	7,920	2,660	10,080
North-Central States east of the Mississippi River:										
Ohio	241	1,900	3,800	1,100	1,050	1,900	2,000	1,100	680	2,050
Indiana	69	900	1,600	180	400	630	1,000	820	450	1,190
Illinois	67	1,600	2,100	300	450	700	750	2,150	770	1,750
Michigan	340	2,200	2,250	2,200	1,500	1,000	2,450	1,400	700	1,800
Wisconsin	......	......	......	......	......	......	......	......	......	......
Total	717	6,600	9,750	3,780	3,400	4,230	6,200	5,470	2,600	6,790
North-Central States west of the Mississippi River:										
Minnesota	......	......	......	......	......	......	......	......	......	......
Iowa	5	190	180	50	180	70	30	300	100	170
Missouri	61	2,250	2,700	1,200	850	2,500	650	4,000	500	2,200
North Dakota	......	......	......	......	......	......	......	......	......	......
South Dakota	......	......	......	......	......	......	......	......	......	......
Nebraska	9	80	120	60	30	200	30	180	170	150
Kansas	138	650	700	350	250	650	180	950	30	650
Total	213	3,170	3,700	1,660	1,310	3,420	890	5,430	800	3,170
South-Central States:										
Kentucky	35	2,100	2,500	500	650	1,700	1,570	1,700	550	1,670
Tennessee	78	1,900	1,800	1,100	900	1,450	670	2,400	450	1,700
Alabama	185	2,300	1,850	1,850	1,250	2,600	870	2,100	650	2,150
Mississippi	252	2,300	1,700	1,650	1,150	2,100	900	1,500	600	1,650
Louisiana	154	520	410	450	300	560	480	450	250	510
Texas	1,400	2,900	1,560	2,200	1,600	1,850	2,600	1,900	1,700	2,300
Oklahoma	305	780	710	1,000	700	500	740	1,200	800	830
Arkansas	334	1,600	1,550	2,200	500	2,500	2,200	2,300	2,400	2,700
Total	2,743	14,400	12,080	10,950	7,050	13,260	10,030	13,550	7,400	13,510
Far Western States:										
Montana	......	......	......	......	......	......	......	......	......	......
Wyoming	......	......	......	......	......	......	......	......	......	......
Colorado	47	180	250	390	350	580	150	800	40	360
New Mexico	76	130	80	130	90	80	100	120	10	100
Arizona	38	36	39	44	50	23	46	32	30	48
Utah	35	230	220	190	220	250	160	260	90	190
Nevada	3	1	6	5	5	4	3	6	4	2
Idaho	18	100	30	60	60	90	40	60	50	80
Washington	81	190	200	170	210	250	190	200	240	270
Oregon	101	240	180	240	240	290	220	190	250	250
California	8,563	6,750	6,836	8,930	8,150	6,425	7,135	6,810	6,900	9,146
Total	9,012	7,857	7,841	10,159	9,375	7,992	8,044	8,478	7,614	10,446
United States (grand total)	15,433	49,438	46,445	37,831	28,850	41,070	36,634	44,104	22,527	48,146

TABLE I.—*Estimated production of peaches in the United States for the 21-year period, 1899 to 1919, inclusive*—Continued.

Group and State.	1909 (Census).	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
North Atlantic States:											
Maine	2	......	......	......	......	......	......	......	......	......	......
New Hampshire	23	56	......	......	44	3	58	24	46	......	43
Vermont	2	......	......	......	......	......	......	......	......	......	......
Massachusetts	92	68	97	51	105	31	152	66	144	......	136
Rhode Island	18	18	22	16	29	14	29	14	......	......	......
Connecticut	270	291	249	128	263	142	335	134	390	......	186
New York	1,736	1,762	1,536	1,400	1,742	530	2,106	1,238	4,823	700	1,648
New Jersey	441	810	440	638	483	1,140	1,275	689	990	832	818
Pennsylvania	1,024	1,533	1,096	660	922	1,541	2,044	1,069	1,848	720	1,046
Total	3,608	4,538	3,440	2,893	3,588	3,401	5,999	3,234	8,241	2,252	3,877
South Atlantic States:											
Delaware	17	810	249	521	312	608	842	346	324	136	277
Maryland	325	1,080	492	672	480	1,032	1,218	600	1,038	235	731
Virginia	243	1,075	318	1,058	312	911	1,358	660	928	510	928
West Virginia	329	598	230	788	132	886	1,164	520	900	680	928
North Carolina	1,344	1,955	437	2,093	598	1,863	1,955	897	1,978	1,150	713
South Carolina	643	1,204	649	1,020	405	1,166	864	545	1,030	998	466
Georgia	2,555	5,395	2,145	6,175	1,950	5,785	5,330	3,510	3,668	6,092	5,895
Florida	115	178	126	190	112	188	177	119	......	......	......
Total	5,571	12,295	4,646	12,517	4,301	12,439	12,938	7,197	9,866	9,801	9,938
North-Central States east of the Mississippi River:											
Ohio	1,036	1,239	1,735	1,055	931	1,653	2,448	1,350	341	174	728
Indiana	1,174	703	1,147	185	1,276	1,128	648	888	518	......	150
Illinois	1,223	140	2,310	82	1,998	1,755	874	780	461	......	790
Michigan	1,687	1,215	2,228	700	1,539	1,247	2,360	2,010	744	85	480
Wisconsin	1	......	......	......	......	......	......	......	......	......	......
Total	5,121	3,297	7,420	2,022	5,744	5,783	6,330	5,028	2,064	259	2,148
North-Central States west of the Mississippi River:											
Minnesota	1	......	......	......	......	......	......	......	......	......	......
Iowa	23	16	240	24	632	472	112	64	......	......	3
Missouri	1,485	1,440	2,700	900	4,320	3,780	3,300	1,050	728	......	828
North Dakota	......	......	......	......	......	......	......	......	......	......	......
South Dakota	......	......	......	......	......	......	......	......	......	......	......
Nebraska	110	150	36	240	210	192	120	30	......	......	......
Kansas	25	2,432	851	2,016	875	1,760	2,442	150	......	......	80
Total	1,544	4,038	3,827	3,180	6,037	6,204	5,974	1,294	728	......	911
South-Central States:											
Kentucky	1,623	770	770	1,210	1,430	1,980	1,320	880	1,100	110	726
Tennessee	1,579	1,440	360	2,820	1,140	2,640	2,460	900	595	833	978
Alabama	1,417	1,980	840	2,760	1,140	2,310	2,640	1,110	1,281	2,440	1,678
Mississippi	1,157	1,340	460	1,800	1,020	1,440	1,540	400	......	......	......
Louisiana	291	488	190	693	460	356	456	587	......	......	......
Texas	730	3,400	1,204	4,140	2,107	1,196	4,081	2,860	1,728	2,333	2,760
Oklahoma	358	1,460	656	2,121	860	220	2,408	230	798	167	1,007
Arkansas	1,902	2,000	2,346	4,524	3,120	3,180	5,940	750	1,824	217	3,639
Total	9,057	12,878	6,826	20,068	11,277	13,322	20,845	7,717	7,326	6,100	10,788
Far Western States:											
Montana	......	......	......	......	......	......	......	......	......	......	......
Wyoming	......	......	......	......	......	......	......	......	......	......	......
Colorado	692	346	363	1,035	360	1,025	650	405	1,096	959	902
New Mexico	32	50	86	84	52	106	154	40	124	34	122
Arizona	50	42	51	54	57	60	60	56	......	......	......
Utah	143	195	208	323	284	380	212	84	1,365	1,050	1,500
Nevada	3	2	10	10	8	9	7	1	......	......	......
Idaho	19	60	81	112	92	120	162	25	211	51	222
Washington	84	348	320	445	446	486	566	415	1,747	575	1,899
Oregon	179	317	190	292	311	387	432	276	273	93	514
California	9,267	9,765	7,412	9,308	7,150	10,387	9,768	11,733	15,724	12,959	17,625
Total	10,469	11,125	8,721	11,663	8,760	12,960	12,011	13,035	20,540	15,721	22,784
United States (grand total)	35,470	48,171	34,880	52,343	39,707	54,109	64,097	37,505	48,765	34,133	50,446

There is rarely a season in which the crop is not materially reduced in some of the important peach-producing regions by the occurrence of adverse conditions of some kind, the effect upon the total crop of the country depending obviously upon the importance of the regions affected and the severity of the conditions. On the other hand, occasional seasons occur when conditions are favorable in all or nearly all of the important commercial districts, and the result is an extremely large crop, as in 1915, and correspondingly low prices for much of the fruit.

The principal regions from which peaches were shipped in the fresh state in 1914 are presented on the map shown as figure 3 in Department Bulletin No. 298, entitled "Peach Supply and Distribution in 1914." On this map the number of carloads from each region and the general period during which the fruit from different regions was being shipped are shown.

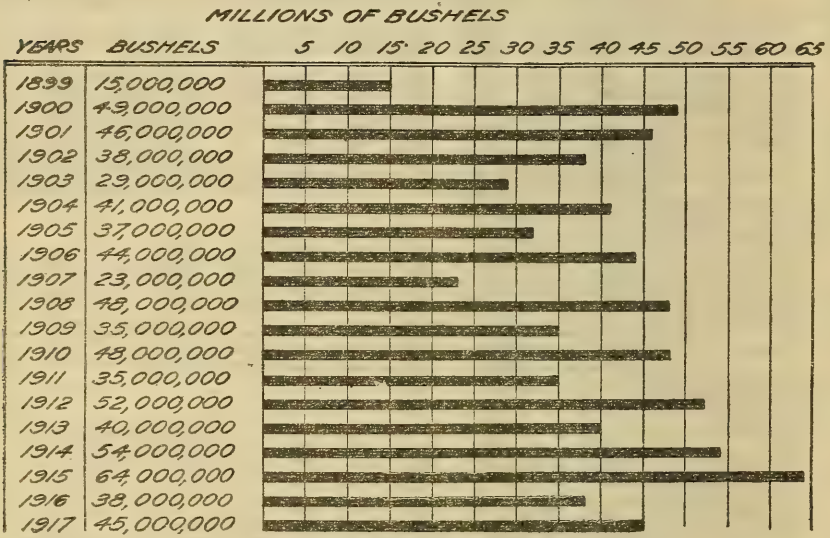


FIG. 4.—Diagram showing the annual farm production of peaches (in bushels) in the United States for the 19-year period from 1899 to 1917, inclusive. The farm production in 1918 was 34,000,000 bushels; in 1919 (September estimates), 50,000,000 bushels. The commercial crop, in distinction from the farm production, for each of the past three years was as follows: In 1917, 29,000,000 bushels; in 1918, 21,000,000 bushels; in 1919 (September estimates), 29,000,000 bushels.

The peach season in each State and its relation in point of time to that of other States is clearly shown in figure 5. The height of the peach season in each State named in figure 5, with the exception of Florida and California, is during the Elberta period, that variety comprising a large proportion of the commercial crop in most States. In some regions it is practically the only variety shipped in quantity.

The estimated average annual peach production by States for the 5-year period, 1912 to 1916, inclusive, is shown in figure 6. It will be noted that the production of "all other States" is 275,000 bushels and that the combined production of the five States named accounts for all except 4,000 bushels of that quantity.

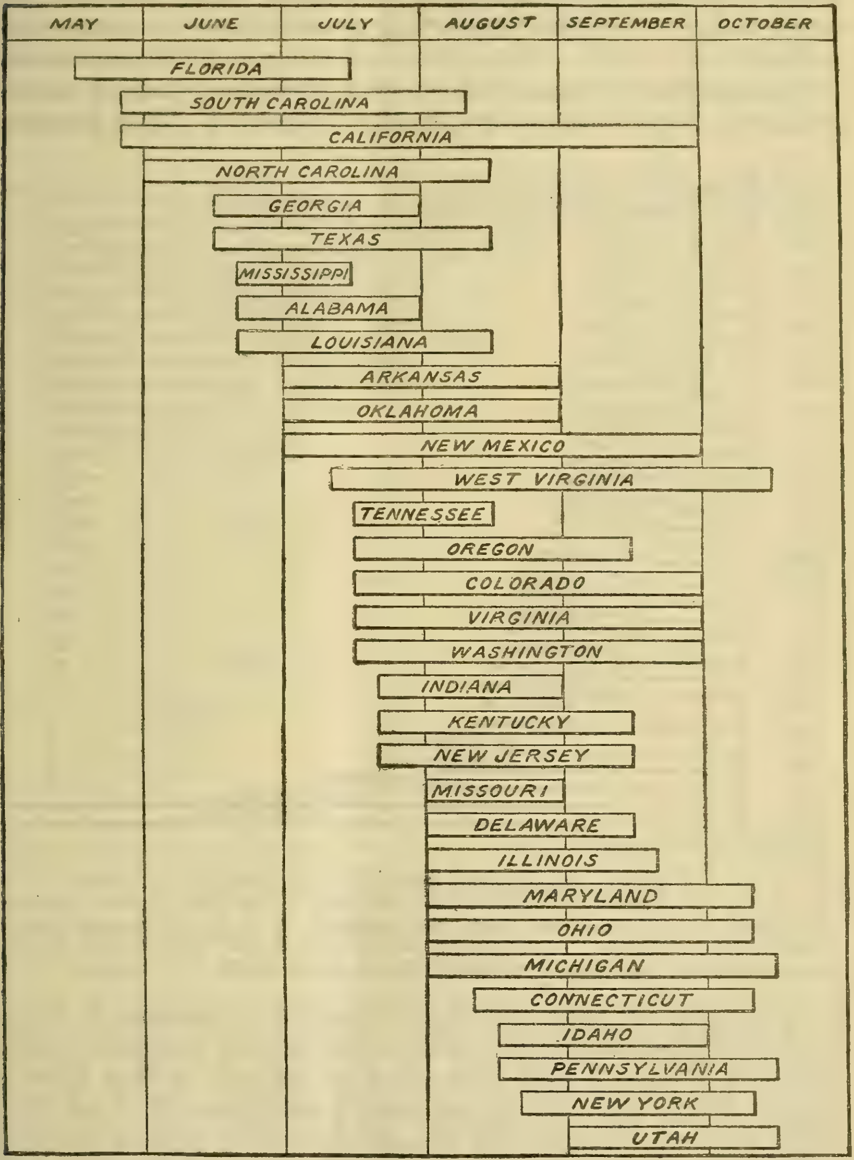


FIG. 5.—Diagram showing the peach-shipping season in each of the principal peach-producing States. (From Department Bulletin 298.)

The estimates on which the averages given in figure 6 are based represent the total crop rather than the commercial portion. This is illustrated in the estimates given for New York, in which there are large commercial interests, and in Kansas, in which the commercial interests are almost negligible. Assuming that these estimates are accurately proportioned, the large number of small home orchards in Kansas possessed in the aggregate during the 5-year period represented in figure 6 a larger producing capacity than the commercial orchards in New York. Other similar examples might be pointed out.

The shipment of fresh fruit in 1914 from the principal peach-producing States is shown graphically in figure 7. This diagram, however, does not show the relative commercial interests so far as California is concerned (see Table I and figure 6 for relative total production), since a large proportion of the crop in that State is used for drying and canning, and hence is not reported in fresh-fruit shipments. Furthermore, the shipments shown in figure 7 are for a single season, and the relative position of many of the States might be markedly different in other seasons, depending largely on the occurrence in different regions of climatic and other conditions that are favorable or otherwise to the peach crop.

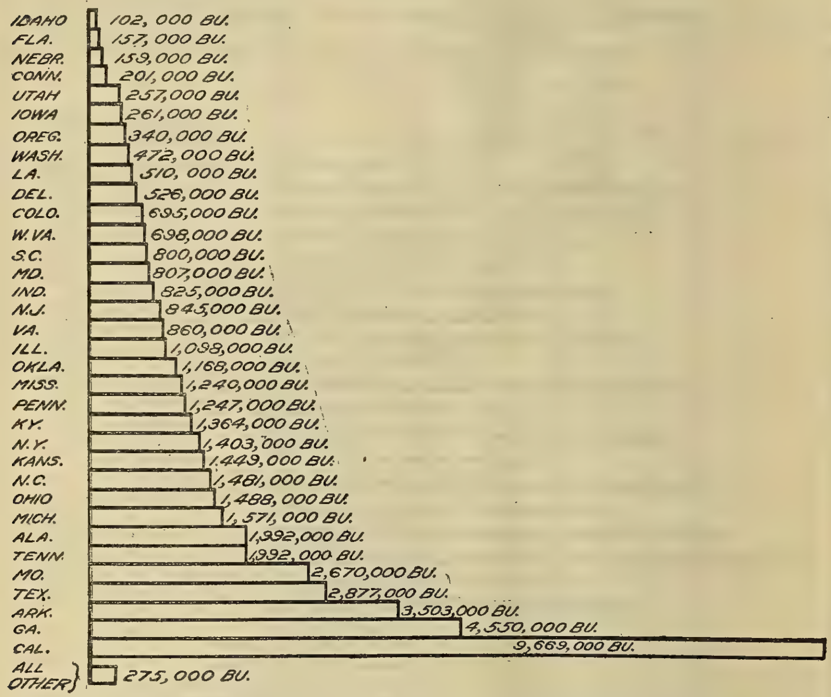


FIG. 6.—Diagram showing the estimated annual average production of peaches in the principal peach-producing States, for the 5-year period from 1912 to 1916, inclusive. The production of five of the States not separately shown in the diagram, but included under "All other," was as follows: New Mexico, 87,000; Massachusetts, 81,000; Arizona, 57,000; New Hampshire, 26,000; Rhode Island, 20,000.

OUTSTANDING FEATURES OF THE PEACH INDUSTRY.

A few features of the peach industry need special mention in the present connection. From the variety standpoint, the preponderance of the Elberta in most of the producing centers and the selection of special varieties for drying and for canning in California are of interest.

The gradual change from decade to decade in the geography of peach growing may also be noted. In certain regions where 20 years ago there was a commercial orchard on nearly every farm, few peaches, or even none, are grown for shipping at the present time. In one or two other regions large quantities of peaches have been produced in recent years on trees interplanted in apple orchards. As the apple trees developed and required more space the peach trees have been removed. Thus the production of peaches is decreasing in these regions, and in the near future the industry doubtless will disappear. Such changes have characterized the peach industry in a marked degree.

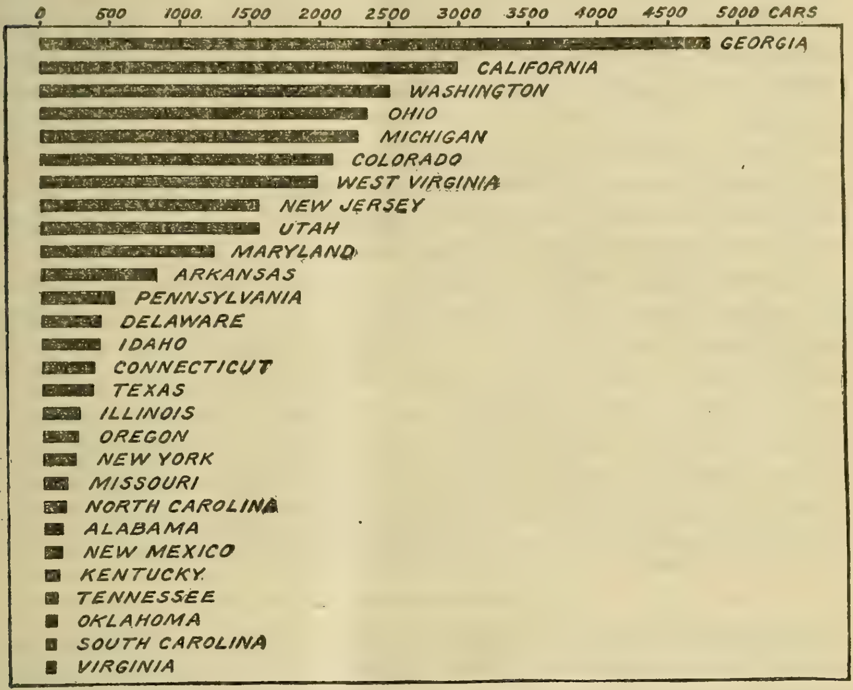


FIG. 7.—Relative bulk of peach shipments in car lots from the principal peach-producing States in 1914. (From Department Bulletin 298.)

IMPORTANT COMMERCIAL DISTRICTS AND VARIETIES, BY STATES.

NEW ENGLAND STATES.

MAINE.

Distribution.—It is substantially true that peaches are not grown in Maine. This is primarily on account of the low winter temperatures that normally occur. The shortness of the growing season is also a factor.

A very few small orchards have been planted in York County, in the southern part of the State, one at least in Lincoln County, and an occasional tree or two may be found in some parts of Cumberland, Oxford, and possibly other counties. The crop, however, is very uncertain.

Varieties.—There is no generally recognized list of varieties for this part of the country. The Triumph, Greensboro, Carman, Champion, Belle, Crosby, and possibly others have been planted. The New York Agricultural Experiment Station in Circular 15 (revised) names the Crosby, Chili, Elberta, Gold Drop, and Stevens as the five varieties most hardy in wood of those grown in New York. Four of these varieties, with the Triumph substituted for Elberta, are also given as the hardiest in bud. While hardiness in tree and bud is an essential characteristic of a variety for the northern extremes of culture, some of the best experience available indicates that varieties later than the Belle are not likely to mature in the average season, and even varieties ripening with the Belle may sometimes fail to mature because of the shortness of the season.

NEW HAMPSHIRE.

Distribution.—Small commercial peach interests have been developed in a few localities in the southern and southeastern parts of New Hampshire. These interests center largely about Wilton in Hillsborough County, about Derry in the southern part of Rockingham County, and about Stratham and Greenland in the eastern part of that county. A few trees are more or less widely distributed in other sections of the southern part of the State, but mostly in gardens and small home plantings.

Varieties.—The varieties most commonly planted are the Greensboro, Carman, Mountain Rose, Champion, Early Crawford, Foster, Belle, Elberta, Late Crawford, and Crosby.

VERMONT.

Distribution.—Peaches are not planted commercially in Vermont. A few trees may be found in the southeastern part of Windham County about Brattleboro, and an occasional tree is growing in other parts of that county, as well as about Isle La Motte in Grand Isle County. This location is on an island in Lake Champlain.

Varieties.—No definite suggestions concerning varieties are offered aside from the obvious fact that only the hardiest sorts should be selected,[1] and even these are likely to prove very uncertain as to crop production.

MASSACHUSETTS.

Distribution.—Peaches are somewhat widely distributed in Massachusetts, except perhaps in the western part of the State. The principal areas of commercial production are within the more important apple-growing districts. However, not many peaches are shipped long distances even from the larger orchards, local markets absorbing most of the fruit. The principal localities which admit of definite designation as peach-producing centers are enumerated below.

The largest production is probably in the central part of the State in Worcester County, Warren in the southwestern part of the county, Grafton in the southeastern, and Bolton in the east-central part being community centers of some prominence. The Bolton section is practically a part of the Littleton and Marlboro sections in the western part of Middlesex County, in which peaches are locally important. They are also grown more or less at other points in this county and in Essex County, the northeasternmost county of the State, centering in a general way in the locality of Haverhill and West Newbury. Small orchards of local importance are found at various points in all the other counties in the eastern and southeastern parts of the State. Farther west, Wilbraham in Hampden County and Amherst in Hampshire County, with various other local points, may also be included in the present inventory of small producing centers. In some sections peaches were formerly interplanted in apple orchards, but such peach interests have now largely gone out as the apple trees have developed.

Varieties.—The Greensboro, Carman, Champion, Belle, and Elberta constitute the principal sorts grown.

RHODE ISLAND.

Distribution.—There are no special centers of peach production in Rhode Island, but orchards planted for commercial purposes occur more or less widely throughout the State, the larger orchards occurring in Newport, Providence, Washington, and Bristol Counties, in the order named.

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[1] Concerning the relative hardiness of varieties, the New York Agricultural Experiment Station (Circular 15, revised) states that the five varieties of peaches most hardy in wood are the Crosby, Chili, Stevens, Gold Drop, and Elberta. The Crawfords are considered most tender in wood. The five varieties of peaches most hardy in bud are the Crosby, Chili, Triumph, Gold Drop, and Stevens. The five most tender in bud are the Early Crawford, Late Crawford, Chairs, Reeves, and Elberta.

Varieties.—The varieties grown are substantially the same as those planted in Connecticut and Massachusetts.

CONNECTICUT.

Distribution.—Peach growing is more or less widely distributed in most parts of Connecticut, except in Litchfield County, in the extreme northwestern part of the State, where few peaches are grown. The district of particular importance commercially, however, is the central part of the State, in the Connecticut River valley from about the region of Hartford southward and including areas in most parts of New Haven County. Representative towns in this district may be named, as follows: Farmington, Glastonbury, and Southington, in Hartford County; Durham and Middlefield, in Middlesex County; Cheshire, Guilford, Milford, Oxford, and Wallingford, in New Haven County; and Greenwich, Norwalk, and other towns in the southern part of Fairfield County adjacent to the shore of Long Island Sound. In New Haven County the towns of Guilford and Milford, above named, adjoin the Sound. Peaches are also grown more or less in other towns similarly located between Greenwich and Guilford.

Varieties.—Many growers in Connecticut select varieties with a view to marketing peaches during as long a period as possible. The principal sorts planted are the Greensboro, Waddell, Carman, Hiley, Champion, Belle, Early Crawford, Hale (J. H.), Elberta, Frances, Stump, Late Crawford, Fox, Stevens, Iron Mountain, and Salwey.

MIDDLE ATLANTIC STATES.

NEW YORK.

Distribution.—Though New York is one of the large peach-producing States, the districts in which the principal interests are located are more clearly defined than in many other States. By far the largest output is from the Lake Ontario shore district from Oswego County westward to and including Niagara County. This district consists at most points of a narrow strip only a few miles wide, where the influence of the lake so modifies the climatic conditions at certain periods as to make them especially favorable for peach growing. At a few points this favored belt extends into the northern parts of the second tier of counties, as, for instance, in Livingston County, in which some peaches are produced. This is by far the largest commercial peach district in the State. Another district is that immediately surrounding the "finger lakes," in central-western New York, where at various points peaches are grown in limited quantities. A third district of some importance is in the Hudson River valley and comprises locations along the river in

Orange County and in the southern parts of Dutchess and Ulster Counties. Small quantities of peaches are also grown along the Lake Erie shore, in Erie and Chautauqua Counties, but the interests there, as in many other sections where home orchards occur, are relatively unimportant as compared with those along the shore of Lake Ontario.

Varieties.—The Carman, Champion, Belle, Early Crawford, Elberta, Late Crawford, Stevens, and Salwey are the principal varieties grown. A very large proportion of the product consists of the Elberta variety, it being estimated to comprise 80 per cent of the crop in some localities. There is no close second to the Elberta variety in the peach industry of the State.

NEW JERSEY.

Distribution.—Peach growing has long been a prominent commercial enterprise in New Jersey. Orchards are widely distributed in most parts of the State, but the commercial interests are more or less localized about certain centers. The centers of principal production have changed to some extent because of the incursions of peach yellows, the ravages of the San Jose scale, and for other reasons, but at present the larger regions commercially important are the following: Hunterdon County, in the locality of Lebanon and New Germantown; Monmouth County, about Freehold and Middletown; Burlington County, centering about Moorestown and Burlington; Gloucester County, about Glassboro; Atlantic County, in the vicinity of Hammonton; and Cumberland County, with Vineland as a prominent center of production. Except Hunterdon and Monmouth, the counties named above are located in the southern half of the State. While peaches are widely grown outside the centers mentioned, the counties named indicate the general distribution of the larger interests.

Varieties.—The principal varieties planted at present comprise the following: Greensboro, Arp, Carman, Lola, St. John, Hiley, Champion, Belle, Elberta, Frances, Fox, Iron Mountain, and Krummel. While few orchards, and perhaps none, contain all of these varieties, the list is made up of those which are variously planted in the principal peach sections. In an earlier day the Mountain Rose, Early Crawford, and Reeves were leading commercial sorts, but these are of relatively little importance in New Jersey at the present time.

PENNSYLVANIA.

Distribution.—Peaches are widely distributed in most parts of Pennsylvania, and the large number of good-sized industrial towns and cities in that State furnish local markets for much fruit. Though from many orchards the fruit is shipped in car lots to distant markets, the community interests as a rule are comparatively small, except in a few districts. Probably the most important producing section at present is the southeastern quarter of Franklin County, in which are located several rather large shipping points. This forms a part of the Cumberland Valley—a district which, as a whole, has produced many peaches in the past and doubtless is still the most important peach district in the State. Besides Franklin County, Cumberland, Perry, and Juniata Counties belong in this valley district. Adams and York Counties, located between Franklin and Cumberland Counties and the Susquehanna River, also contain peach orchards of commercial rating; likewise Northampton and Lehigh Counties, in the east-central part of the State. A third district of considerable importance is the lake shore region of Erie County, in the extreme northwestern part of the State.

Varieties.—Carman, Champion, Belle, Ede, Elberta, Fox, Late Crawford, Chairs, Iron Mountain, Geary, Smock, and Salwey are the principal varieties. Few, if any, orchards contain all of these varieties, though the growers, especially those in the Cumberland Valley and adjacent sections, usually aim to plant a considerable number of varieties, with a view to shipping continuously over a long period.

EAST NORTH-CENTRAL STATES.

OHIO.

Distribution.—Peach growing for home use is more or less universal throughout Ohio, but the areas of commercial production are fairly definite. In its commercial aspects, Ottawa County, with its peninsulas and adjacent islands bordering Lake Erie near its western extremity, is far in the lead of any other county; but in this same general lake-shore district there are several other peach-growing counties, including Lucas, Sandusky, Lorain, Lake, and Ashtabula.

Peaches are grown in commercial quantities in some of the counties in the southeastern part of the State, especially along the Ohio River. Lawrence, Meigs, and Athens Counties are mentioned as representative sections of this district. Orchards of some commercial standing also are found in Coshocton and Muskingum Counties, midway between the Ohio River and the geographical center of the State.

Varieties.—The Carman, New Prolific, Elberta, Lemon Free, Smock, and Salwey are the varieties most largely produced.

INDIANA.

Distribution.—Though very generally distributed throughout most of Indiana, the commercial production of peaches is principally in four districts, three of which are in the southern part of the State.

These districts are thus defined: (1) About the junction of the White and Wabash Rivers in Knox and Gibson Counties; (2) in the hilly section in the south-central part of the State, principally in Orange and Lawrence Counties and adjacent parts of the adjoining counties, including Brown, Monroe, Jackson, Washington, and Martin; (3) in most of the counties bordering the Ohio River; and (4) in the northern part of the State bordering Lake Michigan and including parts of Porter and Laporte Counties.

Varieties.—The bulk of the crop consists of the Elberta variety, with the Carman, Champion, and small quantities of a few others as secondary sorts.

ILLINOIS.

Distribution.—Commercial peach growing in Illinois is confined to the southern third of the State, with only such exceptions as are practically negligible. Even in this area the centers of production are rather restricted. In the average season Union County, in the extreme southern part of the State, probably leads in production, but interests of commercial importance are found elsewhere, especially in Johnson, Jackson, Marion, Clay, and Richland Counties. Peach trees are planted in considerable numbers for home use throughout practically the whole State.

Varieties.—The Elberta is roughly estimated by some to comprise as high as 90 per cent of the trees planted in the commercial orchards. A few Carman, Mountain Rose, Ede, Heath, and some others occur. The Hale (J. H.) has been planted in some of the younger orchards.

MICHIGAN.

Distribution.—Peach growing in Michigan is an extensive industry. The area in which it has been developed is more clearly defined than in many other States. It borders Lake Michigan in a narrow belt which includes Berrien County, the southwesternmost county of the State, and extends thence to Leelanau County (which lies between Grand Traverse Bay and the lake) on the north. It is largely through the ameliorating influence of Lake Michigan upon climatic conditions in the areas adjacent to it that the development there of a peach-growing industry has been made possible. As the lake's influence extends inland but a short distance, the peach belt is only a very few miles wide at most points. In the Grand Traverse region, about the bay of that name, peaches are grown to some extent, and the belt extends across Ottawa County into Kent County in the second tier from the lake, though at most points its width covers only a portion of the first tier of counties bordering the lake. Peaches are also produced in some other sections of the State, as, for instance, in Oakland County, in the southeastern part, and in Huron County, in the east-central part. The latter county forms a peninsula between Saginaw Bay and Lake Huron, and thus is bordered by large bodies of water except on the south. However, the commercial peach interests outside the belt above defined are relatively small.

Varieties.—While a considerable number of varieties are grown, the bulk of the commercial crop is made up of a comparatively few sorts, the principal ones being the following: Engle (*Engle's Mammoth*), Kalamazoo, New Prolific, Elberta, Gold Drop, Smock, and Salwey. In the northern part of the Lake Michigan belt two early sorts, the Triumph and St. John, are grown to a limited extent, while the late varieties, such as the Smock and Salwey, are not so much grown as farther south in the State.

WISCONSIN.

Peaches are not grown in Wisconsin except possibly here and there a tree in the southern part of the State. The winter conditions, especially as to temperature, are too severe for successful peach culture.

WEST NORTH-CENTRAL STATES.

MINNESOTA.

Distribution.—Peach growing from a practical standpoint may be said not to exist in Minnesota. The Thirteenth Census reported only 1,571 trees of bearing age for the entire State. Of these, 334 (the largest number in any one county) were in Hennepin County. This county was also reported to have the largest number of bearing trees of both apples and plums.

Varieties.—No recommendations as to varieties can be made.

IOWA.

Distribution.—Peach growing is relatively unimportant in Iowa. The few peaches that are produced are grown very largely in the southern third of the State—that is, south of the latitude of Des Moines. In this area small plantings are more or less widely distributed. Possibly the conditions in the extreme southeastern counties and in those in the southwest having loess soils are more favorable for peaches than in other parts of the State. Formerly peach trees were interplanted in some of the apple orchards in Fremont County, possibly also in some other sections, but as the apple trees have developed the peach trees have been removed.

Varieties.—The Triumph, Greensboro, Carman, and Elberta occur perhaps as frequently as any varieties. Seedlings are not uncommon in some sections where budded varieties have proved very uncertain.

MISSOURI.

Distribution.—The wide distribution of peach trees throughout Missouri is indicated on the map shown as figure 2. It is also shown by the fact that in 1910, according to the Thirteenth Census, 30 per cent of the counties each contained 50,000 or more trees of bearing age, while about 45 per cent of the counties contained 40,000 or more trees old enough to bear fruit. In most of these counties, however, the trees are in home or small local orchards which have little or no commercial importance. Commercial production is confined very largely to the Ozark region along the lines of the St. Louis & San Francisco and the Kansas City Southern Railroads, the principal commercial peach-producing counties being Oregon, Howell, Greene, Lawrence, and Newton. Interests of limited commercial extent also are found at various points along the Missouri River, but principally in St. Louis County in the vicinity of the city of St. Louis and in Jackson County, in which Kansas City is located.

Varieties.—As in many other large commercial peach-producing sections, the Elberta variety comprises the principal part of the crop in most orchards. Relatively small quantities of the Carman, Mountain Rose, Family Favorite, Champion, Belle, Heath, Salwey, and a few others occur in some orchards.

NORTH DAKOTA.

Practically no peaches are grown in North Dakota.

SOUTH DAKOTA.

No peaches are grown in South Dakota except a very few in the Black Hills district, in the southwestern part of the State. Even there they are a negligible factor. No recommendation as to varieties is practicable.

NEBRASKA.

Distribution.—Peach growing in Nebraska is unimportant commercially. Except in four counties—Cass, Otoe, Nemaha, and Richardson—which border the Missouri River south of the Platte River in the southeastern corner of the State, peaches are practically negligible even in local fruit production. Adverse climatic conditions, particularly low winter temperatures that kill the fruit buds, or even the trees, and frosts that occur during the blossoming period constitute the chief limiting factors.

Varieties.—Little attempt is made to grow other than the hardiest sorts. The Alexander, Triumph, Rivers, Champion, Crosby, and Chili varieties are among those most commonly planted.

KANSAS.

Distribution.—For home and local use peaches are planted very generally in the eastern half of Kansas. Very few are grown in the western part of the State. There are a few commercial orchards, located principally in the extreme northeastern corner of the State, especially in Doniphan County, and at a few points along the Arkansas River in Reno, Sedgwick, Sumner, and Cowley Counties. Isolated orchards of local importance are also found in a few counties in other parts of the State.

Varieties.—While the Elberta probably predominates, a number of the other widely planted varieties are grown, such as the Carman, Minnie (*Alton*), Champion Belle, and Hale (J. H.).

SOUTH ATLANTIC STATES.

DELAWARE.

Distribution.—Great changes have taken place in the status of the peach industry in Delaware during the last 25 or 30 years. That portion of the Chesapeake Peninsula which consists of Delaware and the Eastern Shore counties of Maryland early became a famous peach-producing region; in fact, it was one of the first regions in the country in which peach growing became a great industry.

Peach growing reached its zenith in New Castle County in the late seventies. With the extension southward of peach yellows, the center of the industry in Delaware reached the vicinity of Wyoming, in Kent County, about 1880 to 1885, when probably the production was greater than at any time since. Though considerable change has occurred from decade to decade, the central part of Kent County contains relatively large interests at present. It is probable that they have increased somewhat since the Thirteenth Census was compiled.

The trend of the industry following the period of its greatest development is indicated by the census figures presented in Table II.

TABLE II.—*Peach trees of bearing age in the different counties of Delaware and in the entire State.*

Census of—	Counties.			Entire State.
	New Castle.	Kent.	Sussex.	
1890	588,119	2,335,740	1,597,764	4,521,623
1900	37,689	824,430	1,579,531	2,441,650
1910	58,175	596,069	523,158	1,177,402

Since the late seventies New Castle County, the northernmost county in the State, has not been prominent for peach growing as compared with Kent and Sussex Counties, and, as Table II shows, there was a decided decrease in the number of bearing trees in Delaware during the decades included in the tabulation, though from 1890 to 1900 the decrease in Sussex County was comparatively small. This decline in the extent of the industry is probably traceable principally to three causes—the destruction of the trees by yellows and by the San Jose scale and the competition of the fruit with that produced in other regions. During the years when peach growing in Delaware was at its height there was comparatively little competition in the industry, since extensive planting of peaches had not yet occurred in many sections.

The areas about Camden and Wyoming in Kent County, about Bridgeville in Sussex County, and about Milford in both these counties are among the more important centers of production at present, but in a general way peaches are grown more or less throughout these two counties in localities within easy hauling distance to shipping stations.

Varieties.—Comparatively few varieties make up the bulk of the crop. These are principally the Carman, Belle, Reeves, Elberta, and Frances, with the Elberta largely predominating.

MARYLAND.

Distribution.—For a century and more, peach growing in Maryland has been a prominent agricultural enterprise. This applies particularly to certain Eastern Shore counties and to Anne Arundel County, on the western shore of Chesapeake Bay. During the late eighties and the nineties large interests were developing in Washington County in the western part of the State. Probably the zenith of peach growing on the Eastern Shore was reached about 1875 to 1885, coincident with its largest extension in Delaware. Subsequent changes have been not unlike those that have occurred in Delaware. These changes are suggested by the census figures presented in Table III.

TABLE III.—*Peach trees of bearing age in certain counties in Maryland.*

Census of—	Counties.			
	Caroline.	Kent.	Queen Anne.	Washington.
1890	670,828	1,758,005	1,287,496	124,105
1900	628,284	484,249	565,640	828,352
1910	175,339	190,594	119,804	260,596

The figures in Table III are self-explanatory. The decline of peach growing shown was due to a combination of factors. The most potent influences were probably the prevalence of yellows and the competition in the markets with fruit produced in other regions where large interests were developed.

The wide distribution and destructiveness of the San Jose scale during the late nineties and the first part of the following decade also caused a marked decrease in the number of trees. Even at present the industry is undergoing change, as indicated by the fact that since the census of 1910 commercial peach growing in Caroline County has practically ceased. Meanwhile, the industry has become of increasing importance in some of the more southern counties on the Eastern Shore. Of the counties which were early prominent, Kent and Queen Anne, both of which border Chesapeake Bay, continue to produce considerable quantities of fruit. In addition Talbot, Dorchester, Wicomico, and Worcester Counties, all on the Eastern Shore, contain peach interests of considerable importance. Washington County, in the western part of the State, continues as an important factor, and extensive peach interests have been established also in Allegany County.

Varieties.—In western Maryland many of the orchards contain a rather long list of varieties planted with a view to supplying the markets continuously throughout the entire peach season. Such orchards commonly are made up of about the following sorts: Greensboro, Carman, Hiley, Mountain Rose, Champion, Belle, Reeves, Elberta, Fox, Late Crawford, Stevens, Smock, Salwey, and Bilyeu. In the Eastern Shore orchards relatively few peaches that ripen later than the Elberta are grown, though some Late Crawford and Chairs are still produced. The Ray and Hale (J. H.), ripening in the same general season as the Elberta, are found in some orchards. The Carman, Hiley, Champion, and Belle varieties make up the bulk of the fruit that ripens before the Elberta.

VIRGINIA.

Distribution.—Peaches are widely grown for home use throughout nearly all parts of Virginia. Commercial orchards also are found at many different places in certain parts of the Piedmont and Valley regions. The extent of the commercial interests has varied considerably in the past. In recent years the attention of fruit growers in this State has been so largely given to the apple crop that peach growing has become a relatively small factor in the fruit industry. The principal Piedmont counties, from the standpoint of commercial peach enterprises, are Albemarle, Nelson, and Amherst. In the Shenandoah Valley, Frederick and Shenandoah Counties doubtless lead in importance at present, but Rockingham, Augusta, Alleghany, Botetourt, and Roanoke Counties call for mention in this connection.

Varieties.—The varieties principally grown are the widely distributed sorts, the most prominent being the Carman, Hiley, Belle, Early Crawford, Oldmixon Free, Elberta, Late Crawford, Heath, Salwey, and Bilyeu (*Comet*).

WEST VIRGINIA.

Distribution.—While peaches are grown locally more or less in many places throughout West Virginia, the important commercial interests are located chiefly in the counties that make the eastern panhandle region of the State, including Jefferson, Berkeley, Morgan, Hampshire, Mineral, Hardy, and Grant Counties. Of these, Morgan, Hampshire, and Mineral Counties are by far the most important from the standpoint of peach production. In comparison with them the peach interests in Jefferson and Berkeley Counties are rather small. The orchards in these two counties are somewhat widely distributed, however, being located with reference to the railroads that cross them in various directions. It is true, likewise, that in the other counties named the locations of orchards have been determined largely by the transportation facilities, and accordingly they are less widely distributed than in Jefferson and Berkeley Counties. In Morgan and Mineral Counties peach growing is confined to locations within a very few miles of the Potomac River, while in Hampshire, Hardy, and Grant Counties, which are traversed by the south branch of the Baltimore & Ohio Railroad, the orchards occupy sites on the ridges of the mountains which characterize the topography and parallel with which the railroad is located.

Peaches are also a commercial crop of limited proportions at points in the western part of the State along the Ohio River. Cabell and Wood Counties, in which are located, respectively, the cities of Huntington and Parkersburg, are relatively important in that part of the State.

Varieties.—While much the same varieties are grown in West Virginia as are produced in the peach-growing districts to the southward, the relative importance of different varieties is not the same as it is in most other districts. In most of the orchards in the Potomac River valley and adjacent sections the varieties have been selected and planted with a view to furnishing a fairly uniform and continuous supply of fruit throughout a long shipping season. It is important, therefore, from the producer's standpoint to have the fruit ripening in a uniform sequence in order that the crews may be regularly and economically employed. The following varieties are the ones largely grown: Carman, Connet (*Southern Early*), Champion, Hiley, Belle, Oldmixon Free, Elberta, Late Crawford, Stevens, Beers Smock, Heath, Salwey, and Bilyeu.

NORTH CAROLINA.

Distribution.—The principal commercial peach-producing district of North Carolina at present is in what is commonly called the sand-hill region. From the peach-growing standpoint this refers primarily to Moore County, though in adjacent areas in Montgomery County, which borders Moore on the west, considerable quantities are produced. Candor, in the latter county, and Aberdeen, Southern Pines, and Eagle Springs are representative shipping stations in Moore County. The peach industry is being extensively and rapidly increased in this district at present.

A relatively small peach enterprise is located in the northwestern part of the State, centering about Mount Airy, in Surry County. Some tendency to establish peach orchards at some of the higher elevations in the western sections of the State is also reported. Again, in the southeastern part of North Carolina, at points in Duplin, Sampson, Pender, Bladen, and Columbus Counties, rather extensive plantings have been made. Few of these, however, have as yet come into bearing.

Great numbers of seedling peach trees are grown in the mountain regions, foothills, and adjacent areas in western North Carolina and adjoining States. The fruit of these is harvested and the seeds assembled for sale to nurserymen who plant them for the growing of stocks to be used in propagating peach trees. Western North Carolina thus supplies large quantities of the "natural peach pits" used by nurserymen.

Varieties.—The principal varieties are the Mayflower, Victor, Alexander, Yellow Swan, Greensboro, Arp, Carman, Connet, Hiley, Belle, and Elberta, with the last-named variety largely predominating.

SOUTH CAROLINA.

Distribution.—Peach growing for home use is widely distributed in South Carolina, as it is in most Southern States. Commercial interests are located rather widely, but especially in Edgefield County along the Savannah River and in Saluda County. Orchards having a commercial status also are found in Calhoun, Richland, Kershaw, and Lancaster Counties. These counties occupy a strip through the center of the State which extends from the western extremity of the sand-hill region to the eastern extremity of the Piedmont region. In the western part, orchards occur more or less in Greenville, Pickens, and Oconee Counties.

Varieties.—The Mayflower, Carman, Belle, and Elberta varieties comprise the bulk of the crop.

GEORGIA.

Distribution.—According to the Thirteenth Census there were about 10,600,000 peach trees of bearing age in Georgia in 1910, the largest number reported for any one State. In the combined number of trees of both bearing and nonbearing age, Georgia was exceeded by Texas and California.

In yield California is far ahead of Georgia (see fig. 6), but, as noted under California, a large part of the peach crop of that State is used for drying and canning. In shipments of fresh fruit in seasons of a good crop Georgia normally leads all other States.

In general the commercial peach interests of Georgia may be said to be in the central and northern parts of the State. A line extending from Augusta (in the east-central part of the State) in a southwesterly direction toward Albany until it cuts the thirty-second parallel of latitude (which is practically the latitude of Savannah and Americus), and then running directly west to the Georgia-Alabama State line, will divide the State into two sections, of which the northern contains practically all the commercial peach orchards.

The following are the principal counties in which peaches are grown: In the northeastern part of the State, Habersham, White, Banks, Hall, Jackson, Elbert; in the northwestern part, Dade, Walker, Catoosa, Whitefield, Murray, Chattooga, Gordon, Pickens, Floyd, Bartow, Cherokee, Polk, Paulding, Cobb, and Haralson. The above counties are north of the latitude of Atlanta. In the west-central part are Meriwether, Spalding, Pike, Monroe, Harris, Upson, Crawford, Bibb, Marion, Taylor, Macon, Houston, Stewart, and Sumter Counties. In the east-central part are Columbia, McDuffie, Warren, Glascock, Washington, Hancock, Putnam, Jasper, Jones, and Twiggs Counties.

By far the largest center of production is Fort Valley, in Houston County. The next most important centers, on the basis of size, are adjacent areas in Crawford and Macon Counties. Several other counties immediately adjacent to these also contain large interests.

Varieties.—In the central sections the principal sorts are the Mayflower, Greensboro, Dixie Queen, Early Rose, Carman, Waddell, Hiley, Belle, Hale (J. H.), and Elberta. Those in the northern sections are the Carman, Hiley, Belle, and Elberta. Since the very early varieties if grown in the northern sections would compete with the later and more desirable fruit from central Georgia, they are not much planted there. The Elberta is planted in all sections of the State very much more extensively than any other one sort.

FLORIDA.

Distribution.—While peaches are grown more or less generally for home use throughout much of the central highland portion of Florida, the commercial production, measured in carloads, is rather small. The fruit, however, is marketed early in the season, before shipments begin from more northern points. The principal shipping points are in the northeastern quarter of the State, in Putnam, Volusia, and Lake Counties, and in closely adjoining areas in adjacent counties. Representative shipping and production points are Crescent City, Edgar, and McMeekin, in Putnam County; Seville and De Land, in Volusia County; Umatilla, in Lake County; and Lake Geneva, in the southern part of Clay County, which adjoins Putnam on the north. According to the Thirteenth Census Marion and Alachua Counties, adjoining Volusia and Putnam Counties on the west, contain large numbers of bearing trees compared with most other counties in the State, but no important centers of production are designated.

Varieties.—The varieties of commercial importance grown in Florida are few in number. The Jewel is the leading sort, while the Waldo, Angel, and a few others are grown to a limited extent. These all belong to the Peen-to race. They are grown little, if at all, outside of Florida. A few varieties of the South China or Honey race are also grown in Florida, but probably no member of this race equals in importance those of the Peen-to race above named.

EAST SOUTH-CENTRAL STATES.

KENTUCKY.

Distribution.—Doubtless the most important commercial peach district in Kentucky is in the hilly section south and southeast of Louisville, in Jefferson and Bullitt Counties. Shepherdsville and Brooks, in the latter county, are perhaps the largest shipping stations in this district at present. Bedford, in Thimble County, and Bowling Green, in Warren County, are other relatively important centers of production. These localities, except the latter, are in the north-central part of the State, along the Ohio River. Certain other counties bordering that river, such as Campbell, Kenton, and Henderson, produce small quantities of peaches. They are also widely grown in most other parts of the State, but generally not on a commercial scale.

Varieties.—The Elberta is the most prominent variety. The Carman, Belle, Champion, Globe, and a few others are grown in small quantities.

TENNESSEE.

Distribution.—Commercial peach growing in Tennessee is a relatively limited industry, yet many orchards of considerable commercial importance are found in a large number of counties in different parts of the State. Doubtless the largest general district from which peaches are shipped in quantity is the lower portion of the Cumberland or East Tennessee Valley. This district includes shipping points in several counties, of which the following are among the best known: Cleveland, in Bradley County; Sale Creek, in Hamilton County; Dayton and Spring City, in Rhea County; and Harriman and Kingston, in Roane County. Orchards of some commercial standing are found in some other parts of the East Tennessee Valley, as in Knox, Hamblen, and Washington Counties, but the fruit from these sections is relatively unimportant in quantity. Formerly Tazewell and Cumberland Gap, in Claiborne County, were fairly large points of production. Though of much less importance than heretofore, some shipments are still made from these places.

In the Cumberland Plateau region, which as a whole is not regarded as well adapted to fruit growing, Morgan is the only county that requires mention from the standpoint of peach production.

In the Gulf Coastal Plains region, in the western part of the State, peaches are grown commercially to some extent. Orchards are found in Obion, Madison, Gibson, and possibly other counties.

Varieties.—Early Wheeler (*Red Bird Cling*), Greensboro, Carman, Belle, and Elberta varieties make up the bulk of the crop. Not all these varieties are of equal importance in the different sections, and the two first named are not widely grown, but for early sorts they are of some value in most sections of the State.

ALABAMA.

Distribution.—In Alabama there are several regions where peach growing is of considerable importance. Probably the largest interests are in the southwestern part of the State, in Escambia County, centering about Atmore. In the northwestern part, especially in Walker, Winston, Marion, and Franklin Counties, there are many orchards. Jasper, Haleyville, Winfield, and Phil Campbell are representative shipping points in these counties.

Individual orchards of commercial size, varying from a few acres in extent to 60 acres or more, including one reported to contain 1,100 acres, are more or less widely distributed in other parts of the State, especially in the central, eastern, and northern counties. Jackson, Etowah, Cullman, Jefferson, Clay, Chambers, Lee, and Macon are the counties in which the more important of these somewhat isolated commercial orchards occur.

Varieties.—The Elberta is by far the most important variety throughout Alabama. A few earlier varieties, including the Mayflower, Carman, and Belle (*Belle of Georgia*), are grown in some of the orchards.

MISSISSIPPI.

Distribution.—Though peaches are widely distributed throughout most parts of Mississippi, they are grown largely for home use or local markets, the commercial interests being nearly negligible. A few carloads are usually shipped each season from Jasper and Wayne Counties, in the east south-central part of the State; from Union, Prentiss, Pontotoc, and Lee Counties, in the northeastern part; and possibly in some seasons also from certain other sections. The total commercial shipments in any year include but a small number of carloads.

Varieties.—The Elberta is the principal variety. Other varieties commonly grown in Alabama and Georgia also are grown to a limited extent.

WEST SOUTH-CENTRAL STATES.

ARKANSAS.

Distribution.—By referring to the map (fig. 2) it will be seen that the most extensive plantings occur in the western part of Arkansas, gradually decreasing toward the center, with comparatively few in the eastern part of the State. From a commercial standpoint the largest interests are in Benton, Washington, Carroll, and Searcy Counties, in the northwestern part of the State; in Crawford, Sebastian, Franklin, Johnson, Pope, Yell, Conway, and Faulkner Counties, in the Arkansas River valley between Fort Smith and Little Rock; and in Scott, Polk, Sevier, Howard, Pike, and Hempstead Counties, in the western and southwestern parts. At present the largest concentration of interests is probably in Pike County, which is estimated to have 6,000 acres of Elberta peaches, and in Howard County, with an estimate of 2,000 acres of the same variety.

Varieties.—The Elberta so largely predominates that it practically represents the peach industry throughout the State. North of the Arkansas River a few Carman, Mamie Ross, Belle, and several other varieties are grown, while south of the river the Early Wheeler (*Red Bird Cling*) is planted more or less in addition to some of the other minor varieties named above. In some of the more recent plantings in different parts of the State the Early Elberta and Hale (J. H.) are being tried.

LOUISIANA.

Distribution.—Peach growing occupies an unimportant place in Louisiana. While more or less generally distributed over the State, peaches are produced, with few exceptions, only for home use. At a small number of points in Bossier, Claiborne, Lincoln, and possibly other parishes in the extreme northern part of the State small quantities are grown for shipping. This area is in reality a southern extension of the peach district in southwestern Arkansas.

Varieties.—The principal varieties are the same as those grown in other Southern States of the same latitude, the Elberta leading. In the southern part varieties of the Peen-to race, such as those named under Florida, occur to a limited extent.

OKLAHOMA.

Distribution.—The peach interests in Oklahoma are rather variable. No parts of the State are preeminently adapted to peach growing, yet in favorable seasons peaches succeed well throughout most of the region east of the ninety-eighth meridian, which is approximately in line north and south with Enid, El Reno, and Chickasha. Not many orchards are found west of this line, nor are there interests of much importance in the northern tier of counties. By this elimination that part of the State lying east of the ninety-eighth meridian and south of the border counties on the north may be designated as the region in which most of the commercial peach orchards occur. Within this area commercial orchards are found in most of the counties, though with comparatively small concentration of interests in any one locality. Perhaps Guthrie and its immediate environs in Logan County, and Checotah, in McIntosh County, may be designated as representing some of the more important centers at present. On account of its geographic position Oklahoma is subject to mild winters and warm spells during which the peach buds become tender. Not infrequently temperature conditions occur which, though not unseasonably low, may cause serious injury to the fruit buds after they have started. Because of this, peach growing in Oklahoma is probably less thriving than it otherwise would be. For a similar reason, the status of commercial peach growing has changed materially in many localities in a number of other States.

Varieties.—The Elberta comprises so large a proportion of the trees in commercial orchards that hardly any other sort requires mention. A few Early Wheeler trees are grown in some orchards; also Mayflower, Carman, Mamie Ross, Belle, Early Crawford, Chinese Cling, Heath, and some others.

TEXAS.

Distribution.—In general it may be said that peaches are grown more or less throughout most portions of northern Texas. Limited attention has also been given to peach culture in the southeastern section. The principal commercial interests are located in the northeastern part. A line passing through Sherman, Dallas, Waco, and then directly east to the Sabine River, which is the boundary between

Texas and Louisiana, would include the more important commercial peach-producing counties. Important peach interests exist in a considerable proportion of the counties in the region thus outlined, and many stations from which peaches are shipped are located therein. Tyler, Winona, Athens, Jacksonville, Palestine, Pittsburg, Sulphur Springs, Winnsboro, Mount Vernon, Mount Pleasant, and Marshall are more or less typical centers of production in this area. Orchards of considerable size are also found in other counties, where the intersts are somewhat isolated or represent relatively small community enterprises. Such orchards occur in Colorado, Erath, Eastland, Callahan, Montague, and probably in other counties.

Varieties.—The Elberta variety predominates, but others are considerably planted, such as the Arp, Yellow Swan, Early Wheeler, Carman, Mamie Ross, and Slappey. Certain varieties that have been developed in Limestone County appear to possess characteristics that may prove of great value in northeastern Texas and other regions where the climatic conditions are similar. This group includes varieties designated as Tena, Millard, Anita, Toughina, Lizzie, Frank, Barbara, Katie, and several others which ripen about with the Elberta variety and later.

MOUNTAIN STATES.

MONTANA.

Distribution.—It is substantially true that peaches are not grown in Montana. The Thirteenth Census reported 538 trees of bearing age for the entire State, these occurring on 49 farms; also 3,386 trees not of bearing age on 117 farms. In most sections of the State the trees can not survive the winter conditions, but in the sections about Bigfork, Plains, and Hamilton, in the western part, and possibly in some of the other milder localities a few trees have been planted.

Varieties.—Little information can be give regarding varieties. The Triumph, Champion, Foster, and a few others have been planted, but apparently with very uncertain results.

IDAHO.

Distribution.—Peaches are grown to a limited extent for home use in most sections of Idaho in which a commercial fruit industry has been developed, but the commercial peach production is limited very largely to three regions: (1) The Lewiston district, where a large portion of the fruit is grown on a high bench about 3 miles southeast of the town of Lewiston. (2) The Payette district, which contains a larger acreage of fruit than any other district in the State, comprising the areas along the Payette River from its mouth to Horseshoe Bend, along the Snake River between Payette and Weiser, and up the Weiser River as far as Council. While peaches have been planted more or less in different parts of this district, it is in the Payette River valley, in the vicinity of Emmett on the Emmett bench that the most extensive plantings are found. (3) The Snake River Canyon district, which extends for a distance of some 125 or 130 miles along the Snake River eastward from the point where it crosses the State line into Oregon. Fruit is planted in coves and other places along the river where conditions are favorable. The North Idaho, Palouse, Blackfoot, and Idaho Falls districts are not well suited to peach growing.

Varieties.—The Early Crawford, Elberta, and Late Crawford are the varieties principally mentioned by Vincent and Downing.[1] The Early Hale is named for the Snake River Canyon district in addition to the Early Crawford and Elberta. The latter variety is far more extensively grown than any other.

Additional varieties grown in a small way in several regions of the State include the Alexander, Triumph, Carman, Champion, and a few others.

WYOMING.

As in the adjacent parts of the States which surround Wyoming, peach growing is made impossible by the severity of the climatic conditions. One report states that peaches in Woming are grown "only as curiosities. The trees have to be laid down and buried in winter."

COLORADO.

Distribution.—The commercial peach districts in Colorado are located in irrigated valleys. The most important district is in the Grand Valley, in Mesa County. Palisades and Clifton are the largest shipping points. Other sections of some importance are the Gunnison Valley, in Delta County, centering about Delta and Austin; the North Fork of the Gunnison, also in Delta County, centering about Paonia and Hotchkiss; and the Uncompahgre Valley, in Montrose County, centering about Montrose. Small interests also are found in the Las Animas Valley, in La Plata County.

East of the Great Divide the only areas of commercial importance are in the Arkansas Valley about Canon City, in the eastern part of Fremont County, and at a few points in close proximity to the Arkansas River in Pueblo and Otero Counties.

Varieties.—In all of these sections the Elberta is by far the most important variety. Very small quantities, relatively, of a few other sorts, such as the Alexander, Carman, Belle, Heath, and Salwey, are produced.

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[1] Vincent, C. C., and Downing, G. J. Recommended varieties of fruit for Idaho. Idaho Agr. Exp. Sta. Bull. 83, 14 p., map. 1915.

NEW MEXICO.

Distribution.—Peach growing in New Mexico, like the growing of other kinds of fruit there, is confined almost entirely to irrigated valleys. The principal districts and centers where peach growing is important are the following: The Pecos Valley, especially about Carlsbad, in Eddy County; the Rio Grande Valley, with Las Cruces, in Dona Ana County, the most important locality; Otero County, about Tularosa; and the San Juan County district, in the northwestern corner of the State, centering especially about Farmington. Smaller interests exist also in some of the other fruit-growing areas, such as the Mimbres Valley district in Luna County; the Portales section in Roosevelt County, the latter being a recently developed fruit-growing district; the north-central part of the State, in Colfax County, where small areas irrigated by various mountain streams are devoted to peaches; the San Miguel County district; a small district in northern Santa Fe and in southern Rio Arriba counties; and a similar district in the central part of Taos County.

Varieties.—In the three or four most important districts the Alexander, Hynes (*Hynes Surprise*), Carman, Texas (*Texas King*), Mamie Ross, Champion, Elberta, Late Crawford, Crothers, and Salwey varieties are largely grown. In those of small importance the fruit grown consists mostly of the Elberta and Late Crawford sorts.

The Alexander and Hynes (neither of which appears to be much grown) are late in blossoming, while the Texas, Mamie Ross, and Crothers are medium late; hence, they are less likely to be injured by spring frosts than the earlier blossoming sorts.

ARIZONA.

Distribution.—The report of the Arizona Commission of Agriculture and Horticulture for the year ended June 30, 1915, shows that of the fruit trees and vines of the 10 leading kinds imported into the State for the preceding fiscal year, 44.5 per cent, or 94,752 in number, consisted of peach trees. It was further estimated that 30,500 peach trees grown in local nurseries were planted also during the same year.

While peach growing in Arizona has not attracted wide attention from a commercial standpoint, there are three irrigated valleys in which the interests are of considerable local importance—the Salt River Valley in Maricopa County, the Verde Valley in Yavapai County, and the Gila Valley in Graham County.

Varieties.—The Elberta is largely grown. A few Belle, Salwey, and possibly other sorts are occasionally found. According to McClatchie and Coit,[1] a considerable number of varieties do well in the southern valleys in the State, those definitely specified being the Alexander, Dewey, St. John, Briggs, Belle, Elberta, Late Crawford, Wheatland, Krummel, Sylphide, and Salwey.

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[1] McClatchie, A. J., Coit, J. E., and others. Relation of weather to crops and varieties adapted to Arizona conditions. Ariz. Agr. Exp. Sta. Bul. 78, pp. 44–118. 1916.

UTAH.

Distribution.—In Utah the orchard interests are in valleys which, in general, are located to the westward and along the course of the main range of the Wasatch Mountains, in the north-central part of the State. The principal centers of peach production are as follows: The extreme eastern part of Box Elder County, about Willard, Brigham, Honeyville, Deweyville, Tremonton, and Corinne; Weber County, about Ogden, Roy, and Uinta; Davis County, about Clearfield and Woods Cross; Salt Lake County, about Salt Lake City; and in Utah County, about Provo, Springville, and Payson.

Varieties.—One estimate places the Elberta at 90 per cent of the commercial product of the State. The Early Elberta, Foster, Sellers, and a few others are grown in very limited quantities.

NEVADA.

In most parts of Nevada the climatic conditions are not suited to the culture of peaches, and very little attempt is made to grow them.

PACIFIC STATES.

WASHINGTON.

Distribution.—The peach districts in Washington are coincident with the apple districts, though not all of the latter contain peach interests of importance. The most prominent district with reference to peaches is the Yakima Valley, in which this fruit is grown at numerous points between North Yakima, in Yakima County, and the junction of the Yakima and Columbia Rivers, in Benton County; at Kennewick, located a few miles below the mouth of the Yakima River in Benton County; and at Pasco, directly across the Columbia River, in Franklin County.

The Wenatchee Valley, centering at Wenatchee in Chelan County, is the second most important peach district; the third is the Snake River valley, especially that portion included in the southern part of Whitman County, where at various points peaches are grown on a relatively small commercial basis. This valley is virtually continuous with the Lewiston district in Idaho. In the Walla Walla Valley, as in certain other districts, peach interests have been developed on a sufficiently large scale to produce some fruit for shipping, but the two valleys first mentioned are by far the largest producing districts in the State. The Milton-Freewater district in Oregon is a part of the Walla Walla Valley. In all of these valleys most of the peach trees are interplanted in the apple orchards. As the apple trees develop, the peach trees are taken out. As a result, there is at present a more or less rapid and constant decrease in the extent of the peach industry in Washington.

Varieties.—There are no varieties that are in any way characteristic of these districts. The most important sorts are the Triumph, Carman, Champion, Early Elberta, Early Crawford, Elberta, Late Crawford, and Salwey. The Elberta is the principal variety in most localities.

OREGON.

Distribution.—Peaches are grown in Oregon to a considerable extent as fillers interplanted in apple orchards. To this extent, therefore, peach growing in this State is a temporary enterprise. In some sections, however, peach trees have been planted on a somewhat permanent orchard basis. This is the case in The Dalles district in Wasco County, in the Ashland and Merlin districts in the Rogue River Valley, and in the vicinity of Salem in the Willamette Valley. Important valleys where many peaches have been interplanted in apple orchards include such localities as the Milton-Freewater district in Umatilla County, this being a part of the Walla Walla Valley, the Hood River Valley, the Umpqua Valley, and various points in the Willamette Valley in addition to Salem, which is mentioned above.

Varieties.—A large number of different varieties are grown in the various districts, the more important and widely distributed of which include the Alexander, Early Crawford, Early Charlotte, Elberta, Late Crawford, Muir, Phillips, and Salwey. In most instances in the districts where peaches are of special commercial value the problem in selecting varieties is more largely that of securing sorts that ripen at a desired time or are suited to the purpose for which they are to be used than of choosing varieties that will develop well.

CALIFORNIA.

Distribution.—The peach interests of California surpass those of any other State in both quantity and value of the product. According to the Thirteenth Census, there were nearly 1,500,000 more trees not of bearing age in California in 1910 than in any other State, though in number of trees of bearing age Texas and Georgia each surpassed California. Moreover, the industry is highly specialized. While large quantities of fruit are marketed in the fresh state, the planting of varieties intended especially for canning as well as of varieties particularly adapted for drying is extensively practiced in some districts. The relative importance of peaches for canning, compared with the rest of the country, is indicated by the following figures from the Thirteenth Census. (Table IV.)

TABLE IV.—*Quantity and value of canned peaches in California and in the United States in 1909 and 1914.*

States.	Number of cases canned.		Value.	
	1909	1914	1909	1914
California	1,149,590	2,922,637	$3,013,203	$8,685,831
All other States	317,623	485,269	740,495	899,942
Total for the United States	1,467,213	3,407,906	3,753,698	9,585,773

A comparison of the figures presented in Table IV emphasizes the great importance of the canning industry to the peach growers in California. While the proportion varies more or less from year to year, depending largely upon crop and market conditions in the different States, the actual quantity canned in any year in other parts of the country is always small in comparison with the California product.

Practically the entire commercial output of dried peaches in this country is produced in California. It is estimated that about 90 per cent of the crop, as a rule, is either dried or canned and about 10 per cent shipped in the fresh state.

There are two main districts in which a large proportion of the peaches are produced, viz, the Sacramento and the San Joaquin Valleys. In the latter, the peaches are grown largely for canning and drying. In the Sacramento Valley along the foothills the shipping varieties predominate, but in the valley areas large quantities of fruit both for canning and for drying are produced.

According to the report of the California State Commission of Horticulture[1] Fresno County now has about 35,000 acres of peach trees of bearing age—nearly five times the acreage reported for any other one county.

The principal counties from the standpoint of peach growing in the Sacramento Valley and foothills are Placer, Sacramento, Solano, Sutter Tehama, and Yolo; in the San Joaquin Valley, Fresno, Kings, Merced, San Joaquin, Stanislaus, and Tulare; in other parts of the State, Santa Clara, Los Angeles, Riverside, San Diego, and San Bernardino. Orchards are more or less widely distributed throughout various other districts.

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[1] Weldon, G. P. The acreage of fruits, bearing and nonbearing, by counties, in 1915. *In* Mo. Bul. State Com. Hort. [Cal.], v. 5, no. 3, p. 105. 1916.

Varieties.—A large number of varieties are grown in California, but the bulk of the crop consists of comparatively few sorts. For canning, the firm-fleshed yellow clingstone varieties are largely used. The principal cling varieties grown for canning are the Tuskena (*Tuscan*), Hauss, Johnson, Walton, Albright Cling, and Phillips. Of freestone varieties, the Muir and Lovell are canned to some extent, and for drying they are by far the most important. The Elberta is dried in relatively small quantities. Those grown for shipping fresh are the Alexander, St. John, Early Hale, Early Crawford, Foster, Susquehanna, Elberta, McKevitt, McDevitt, Salwey, Levy, and some others.

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L. O. HOWARD, Chief

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THE BROAD-BEAN WEEVIL.

By Roy E. Campbell,
Scientific Assistant, Truck Crop Insect Investigations.

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INTRODUCTION.

The growing of broad or horse beans in California during the last few years has been seriously handicapped everywhere by the presence of the broad-bean weevil (*Bruchus rufimanus* Boh.). The practical impossibility of growing uninfested beans caused the early abandonment of a considerable acreage. The greatest abandonment, however, followed the ruling, according to the Federal Food and Drugs Act, that weevil-infested broad beans are adulterated food, and that their shipment was prohibited in interstate commerce.

The Bureau of Chemistry first ruled that beans infested "to any material extent" could not be shipped (4),[1] but later changed the ruling to allow shipment to any lot which contained "not more than 15 per cent of wormy or weevil-infested beans" (5). The 15 per cent limit is tentative only. Acting under this ruling, a shipment of broad beans from a San Francisco broker was seized in New York, after having been found to be over 25 per cent infested. The broker was tried for violating the Food and Drugs Act, convicted by a jury, and fined $150 (9). Since then many dealers have refused to handle horse beans, while those who continued to deal in them have had to exercise caution that no shipment contained more than 15 per cent infested beans, or else run the risk of confiscation. The numerous confiscations during the past few years of shipments in transit by food inspectors, and the cost of hand picking to keep the infestation within the 15 per cent permitted, has resulted in keeping the price of beans low and reducing the acreage.

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[1] Numbers in parentheses refer to "Literature cited," p. 22.

Although the bean is commonly called the horse bean, the name is somewhat a misnomer, as only about 30 or 40 per cent of the crop is used as stock feed. The larger portion is shipped to New York and other eastern cities, where it is used for food by Italians and Portuguese, and is known as fava. Other names are English bean, Windsor bean, and tick bean.

The horse bean is used also as a green vegetable, and of late years has been planted to a considerable extent as a winter cover crop, especially in fruit orchards. A recent Farmers' Bulletin (8) recommends further plantings along the Pacific coast, the Gulf of Mexico, and the South Atlantic States, not only for the dry beans for human consumption, but also for the green vegetable, stock feed, and green manuring.

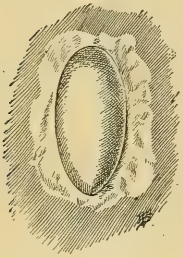


FIG. 1.—The broad-bean weevil: Egg. Greatly enlarged. (Chittenden.)

DESCRIPTION.

THE EGG.

The egg (fig. 1) is elliptical-ovate, about twice as long as wide, a trifle more pointed anteriorly, its surface smooth with no visible sculpture. When first laid it is whitish and glistening, but gradually turns darker. Just before hatching, the black head of the embryo can be seen plainly through the shell.

THE LARVA.

The young larva is pale yellow, with dark or black head and mouth-parts. The full-grown larva is cream colored, with small brown head and black mouth-parts. It is 4.5 to 5.5 mm. long and 2.5 to 3 mm. wide.

THE PUPA.

The pupa when first formed is light yellow or cream colored, with legs and wing-covers whiter. It gradually turns darker, particularly the appendages, until it is light brown before transforming. It measures about 3 mm. wide and 5 mm. long.

THE ADULT.

The adult (fig. 2) is from 3.5 to 4.5 mm. long and a little over half as wide. The general color is black, with white markings on the elytra and pygidium, giving it a somewhat mottled grayish appearance. The head is dark. The basal four joints of the antennæ are reddish brown, the remainder black. The forelegs are reddish brown and black, while the middle and hind pairs are black.

The species closely resembles the pea weevil (*B. pisorum* L., fig. 3), but may be separated by the following characters:

Posterior femora acutely dentate; thorax broad; pattern of elytra well defined; pygidium with a pair of distinct apical black spots------------------*pisorum* L.
Posterior femora obtusely or obsoletely dentate; thorax narrow; pattern of elytra more or less suffused; pygidium with black apical spots lacking or illy defined------------------------------*rufimanus* Boh.

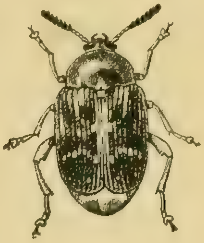


FIG. 2.—The broad-bean weevil (*Bruchus rufimanus*): Adult or beetle. Enlarged. (Chittenden.)

SYNONYMY.

Bruchus rufimanus Boheman.

Bruchus rufimanus Schoenherr, Gen. et Spec. Curculionidum, v. 1, p. 58, 1833.
Bruchus granarius auct. (not L.) Westwood, Curtis, Ormerod, Wood, Riley, Fletcher, Lintner, *et al.*
Mylabris rufimana Boh., Baudi, Deutsch. Ent. Zeitschr., 1880, p. 404.

The *Bruchus granarius* L. is *Laria atomaria* L., Syst. Nat., 12th ed., p. 605, 1776–1778.

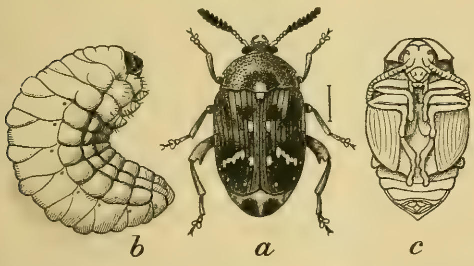


FIG. 3.—The pea weevil (*Bruchus pisorum*): *a*, Beetle; *b*, larva; *c*, pupa. Enlarged. (Chittenden.)

RECORDS OF OCCURRENCE IN CALIFORNIA.

Although horse beans were grown in California as early as 1887, the horse-bean weevil was not recorded as actually established in the United States until September 18, 1909. On that date Mr. I. J. Condit, then collaborator of the Bureau of Entomology, collected live specimens at San Luis Obispo, on growing horse beans (2, 3). Inquiry by the writer among buyers and growers indicates that the weevil was established in California many years before 1909. Mr. P. G. Hammer, San Francisco, writes as follows, "We are quite positive of the date, for in our dealing with this variety of beans the first indication of weevil infestation appeared possibly not later than 1888," from Alameda County. One other broker gives 1893 as the first date infested beans were observed by him from the same locality. Mr. E. A. Bunker, from a personal transaction in 1898, positively remembers that date as the first year infested horse beans were observed by him. Other dates for the different localities given by different bean brokers are as follows: Gilroy, 1890; Watsonville, 1900; Morro, 1900; Oceano, 1903; Halfmoon, 1904; and Sacramento, 1908.

It must be remembered that in none of the above dates were the weevils in horse beans identified as *Bruchus rufimanus*, but there is little doubt that this is what they were. It is, therefore, quite evident that the insect was present in the different localities a number of years before September, 1909.

DISTRIBUTION IN CALIFORNIA.

The principal broad-bean sections in California are around San Francisco Bay and down along the coast to a little below San Luis Obispo. The insect is distributed all over this section, having been taken or reported from the following counties: Sonoma, Napa, Yolo, Sacramento, San Joaquin, San Mateo, Alameda, Santa Cruz, Santa Clara, San Benito, Monterey, and San Luis Obispo (fig. 4). Broad beans are grown in small quantities in many other counties, usually in back yard gardens or in small plots for the green beans. Of late years, in several counties, they have been quite extensively planted as cover crops, particularly in citrus orchards. Unless great care is exercised, which is not often done, in planting uninfested or treated seed, it is safe to say that the broad-bean weevil will be found wherever broad beans are grown and allowed to come to maturity. The writer has found eggs on the green pods of broad beans planted for cover crops in Los Angeles, Orange, and Riverside counties. Cover crops, however, are all plowed under before the weevil has had a chance to develop.

SPREAD IN CALIFORNIA.

The broad-bean weevil probably became established in Alameda County, where horse beans were first grown, about 1888. It next appeared in Santa Clara County in 1890, and in Santa Cruz, Santa Clara, and San Luis Obispo Counties in 1900. By 1904 it was reported from San Mateo County; by 1911 from Sacramento and Sonoma, by 1914 from Yolo and San Benito, by 1916 from San Joaquin, and by 1917 from Napa.

DISSEMINATION.

Although the adult insect is an active creature and doubtless can fly some little distance, from one field to another, or from where beans may be stored to a near-by field, the principal method of dissemination is through the transportation from one locality to another of beans infested with live weevils. It is possible for the adults to escape both after the beans have reached their destination and while they are en route. Planting of these infested beans in a new locality is bound to result in an infested crop.

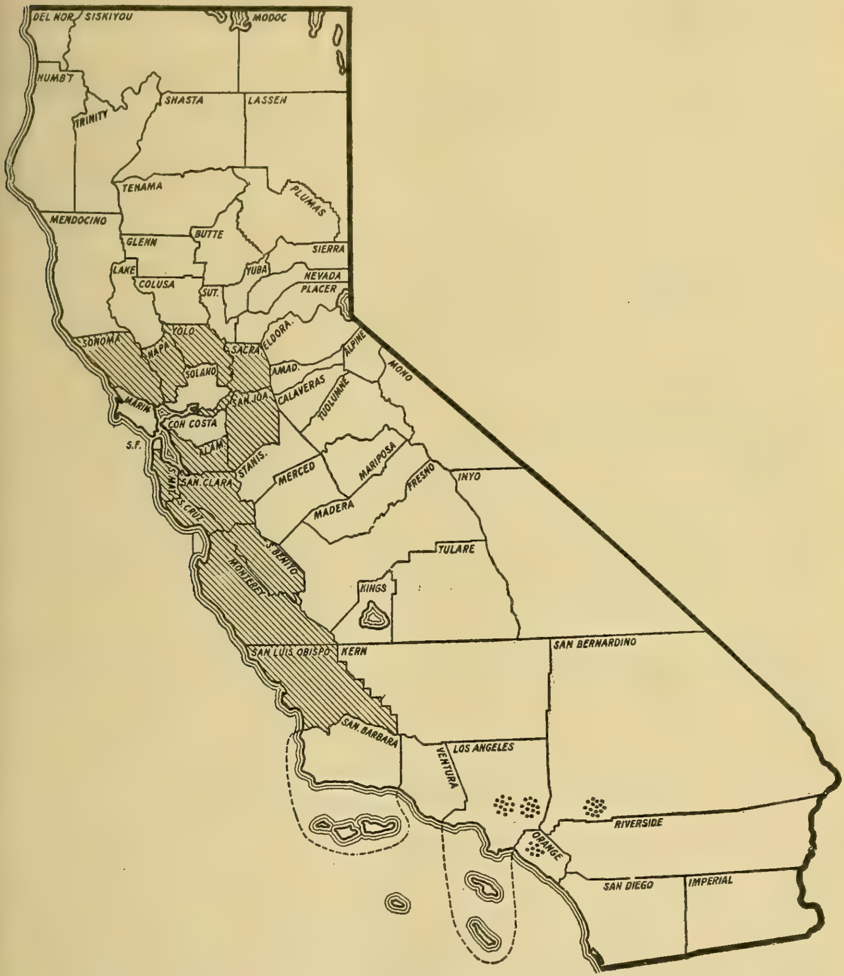


FIG. 4.—Map of California, showing counties from which the broad-bean weevil has been taken or reported.

NATURE OF DAMAGE.

Damage caused by the broad-bean weevil is principally due to the fact that the larva feeds and transforms to the adult within the beans (Pl. I, fig. 3, *a*, *b*). Many adults remain in the beans for several months, and their presence renders the beans unfit for food. Some adults emerge soon after forming, leaving round holes in the beans where the tissue was consumed by the larvæ (Pl. I, figs. 4, *a*, *b*, and 5). This "buggy" appearance lessens the salability of the beans. Infested beans are not only reduced somewhat in weight (see Table I) but their germinating power is also lessened, as will be shown later on.

TABLE I.—*Showing amount of beans consumed by the broad-bean weevil.*

Number of weevils in beans.	Weight of 50 beans.	Weight consumed.	Percentage consumed.
	Grams.	*Grams.*	
None	76,970		
1	74,800	2,170	2.81
2	72,430	4,540	5.89
3	70,150	6,820	8.86

This table shows that approximately 3 per cent of the weight of a bean is consumed by the larva of each weevil developing in it.

EXTENT OF DAMAGE.

It is estimated that the area devoted to broad beans commercially is at present about 3,000 acres for the dry beans, 100 acres for canning green, and 1,000 acres for cover crops. In addition many hundreds of acres are grown in small lots, back-yard gardens, etc., for home consumption. The commercial production of dry beans for market is at present about 50,000 bags, but has been, before weevil damage became so general, as much as 200,000 bags.

After a careful survey of the 1916, 1917, and 1918 crops of horse beans, and of numerous samples taken by food inspectors of the Bureau of Chemistry and the writer, Tables II and III were prepared.

TABLE II.—*Summary of the percentage of infestation of the 1916, 1917, and 1918 crops of broad beans grown in California.*

Infestation.	1916 crop.		1917 crop.		1918 crop.	
	Number of bags.	Per cent of total crop.	Number of bags.	Per cent of total crop.	Number of bags.	Per cent of total crop.
0 to 5 per cent	18,851	38.10	15,372	46.46	6,638	26.75
5.1 to 10 per cent	8,366	16.88	6,855	20.71	5,341	16.16
10.1 to 15 per cent	6,835	13.81	4,904	14.82	4,629	14.01
15.1 to 30 per cent	11,114	22.46	4,852	14.66	10,547	31.93
Above 30 per cent	4,318	8.75	1,107	3.35	3,681	11.15
Total	49,474	100.00	33,090	100.00	33,036	100.00

The damage according to the different horse-bean regions is shown in the following table:

TABLE III.—*Summary of the 1916, 1917, and 1918 crops of broad beans showing the percentage of weevil infestation by localities.*

	1916 infestation.	1917 infestation.	1918 infestation.
Sacramento:	*Per cent.*	*Per cent.*	*Per cent.*
Maximum	41	63	84.3
Minimum	0	0	1
Average	9.09	12.7	22.4
Oceano-Morro:			
Maximum	50	63	17.2
Minimum	0	0	0
Average	14.5	14.5	2.92
Halfmoon:			
Maximum	55	56.6	56
Minimum	0	.5	0
Average	13.6	10.9	16.8
Gilroy:			
Maximum	70	46	....
Minimum	0	1	....
Average	24	16	....

Table II shows that of the entire crop of broad beans for the three years 1916, 1917, and 1918, 31.21, 18.01, and 43.08 per cent, respectively, were above the 15 per cent limit of weevil infestation allowed by the Bureau of Chemistry, and therefore could not be shipped unless hand picked. Table III shows that even the average percentage of infestation for the entire 1916 crop in the Halfmoon and Gilroy regions was above the 15 per cent limit, while the same is true of the Sacramento and Halfmoon districts for the 1918 crop. This table also shows some interesting data on the increase in infestation. Sacramento is a comparatively new district for raising broad beans, and at first the weevil infestation was low, but as planting continued from year to year, and the acreage increased, the percentage of infestation greatly increased, going from a maximum of 41 per cent in 1916 to 63 per cent in 1917 and 84.3 per cent in 1918, while the average percentage of infestation for the same years increased from 9.19 to 12.7, and then to 22.4 per cent. Climatic conditions at Sacramento are adverse to late planting, and early planting as practiced there is favorable to heavy weevil infestation. Unless control measures are practiced, and only uninfested or treated seed is planted, this district soon will be in the same position in regard to the production of horse beans that Alameda County has been in for some years. The low percentage of infestation in the Oceano-Morro district for the year 1918 will be explained later.

Estimates from bean brokers on the reduction in value of broad beans from the infestation of the weevil vary from 25 per cent to total unsalability, depending on the degree of infestation.

The cost of hand picking to remove the weevily beans also depends on the degree of infestation, but it is estimated at about $1.50 per 100 pounds.

Estimates of the reduction on the total horse bean acreage, because of the increase in weevil infestation, range from 25 to 75 per cent. Alameda County was formerly the largest producer, but at present, due largely to the extensive infestation of all horse beans grown there, practically no beans are produced commercially. It is also estimated that if weevil infestation could be prevented, the acreage for the dry-bean crop alone would be increased from 100 to 300 per cent in that county.

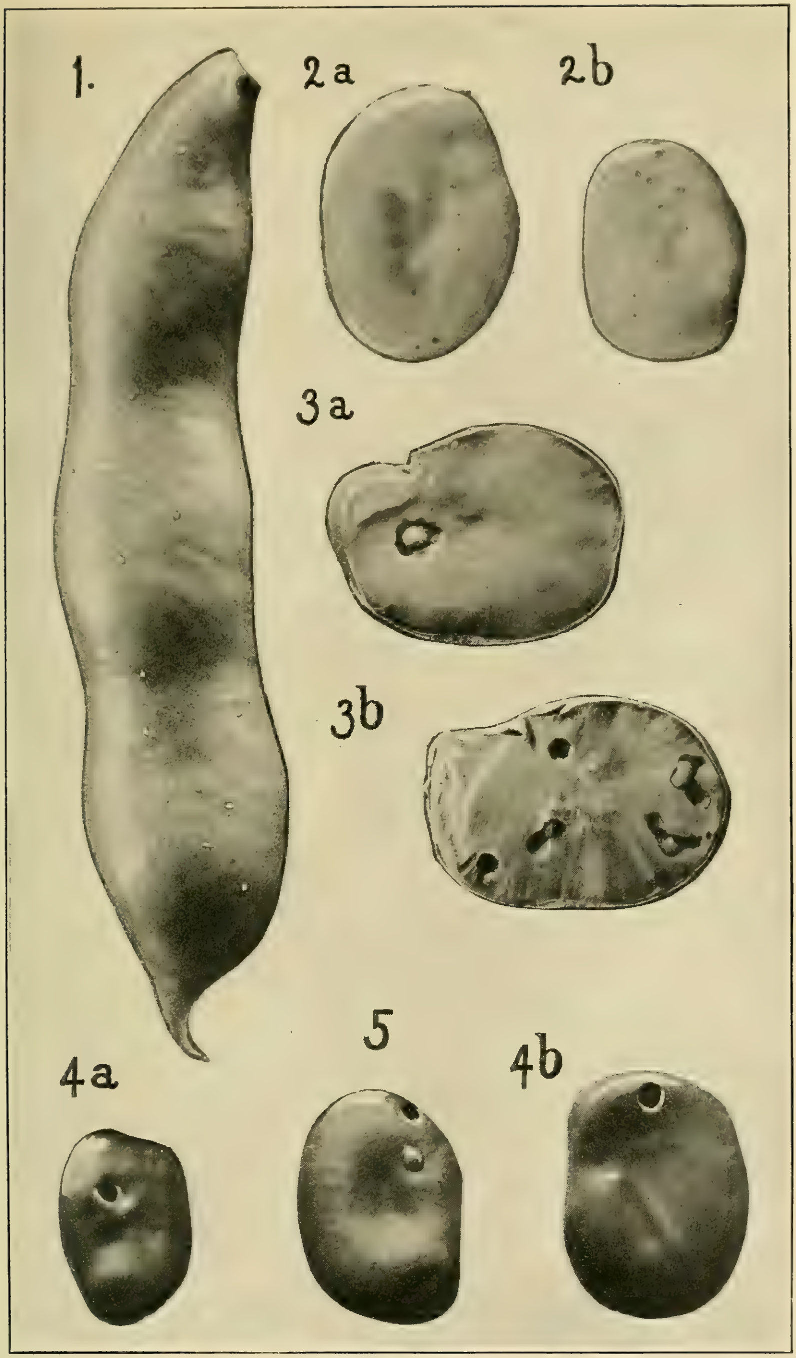
It will be seen from Table III that there is considerable variation in the percentage of infestation in the different districts. There is also great variation in the number of weevils developing in a single bean. In the case of the pea weevil *B. pisorum* (fig. 3), with a very similar appearance and life history, only one weevil develops in a seed, but with the broad-bean weevil there are often two and three adults in a single bean, while it is not at all rare to find four, five, and even six. The following table illustrates this:

TABLE IV.—*Summary of the percentage of broad beans infested with different number of weevils.*

Number beans examined.	Locality raised.	Year raised.	Number weevils per bean.	1 weevil per bean.	2 weevils per bean.	3 weevils per bean.	4 and 5 weevils per bean.	Total per cent infested.
1,000	Hayward	1915	371	367	186	63	13	62.9
1,000	do	1916	331	324	216	95	34	66.9
1,000	do	1917	781	164	46	9	0	21.9
1,000	Stockton	1917	880	105	14	1	0	12
1,000	Hayward	1917	573	227	140	29	31	42.7
Average per cent			58.9	23.7	12	3.9	1.5	41.1

LIFE HISTORY.

The eggs are laid on the outside of the green pods, being cemented to the latter by a glutinous secretion. They are laid singly and indiscriminately over the surface of the pods (see Pl. I, fig. 1) without apparent reference as to whether the position is favorable or unfavorable to the newly hatched larva getting into the young bean. The number of eggs on a pod also bears no relation to the number of beans it contains, as often the former exceeds by many times the number of larvæ which might develop therein. One pod 4 inches long was observed with 55 eggs deposited on it. The following table shows the variation in number of eggs laid on a pod.



The Broad-Bean Weevil.

1, Broad-bean pod showing eggs laid upon its surface; 2, broad beans showing entrance holes or "stings" of larvæ; 3, *a*, *b*, broad beans cut open to expose larvæ of the broad-bean weevil and the damage they have done; 4, 5, infested broad beans showing emergence holes made by adult weevils in leaving the seed. In figure 5, below the emergence hole, is shown a "window."

TABLE V.—*Number of eggs of Bruchus rufimanus deposited on pods at Hayward, Calif.*

Date.	Number pods on plant.	Total number eggs per plant.	Number eggs per pod.		
			Maximum.	Minimum.	Average.
1916.					
April 20	12	88	17	2	7.3
Do	19	153	17	1	8
April 25	5	30	18	2	6
Do	12	70	29	1	5.8
Do	14	119	22	1	8.5
Do	8	71	19	4	8.8
Do	8	48	9	3	6
Do	11	115	23	2	11.3
Do	10	144	42	8	14

No eggs were observed by the writer except on the pods, the latter varying in size from less than an inch to full growth of 5 inches. Most of the eggs are found on the larger pods.

Although adults have been noticed a number of times crawling over the plants during the day, the act of oviposition was never observed. It is probable that it occurs late in the evening or at night.

Efforts to induce oviposition in captivity were not successful, so the total number of eggs laid by individual females was not ascertained.

The duration of the egg stage was found to be from 9 to 18 days, with an average of 13 days. A few days before hatching the dark head of the embryonic larva can be seen plainly through the eggshell. The larva draws its head back, leaving about one-quarter of the shell hollow. For about a day the position appears to be unchanged, then gradually as the larva eats through the side of the shell attached to the pod and into the pod the clear space in the shell becomes larger until the latter is entirely empty, having a glassy and transparent appearance. It usually takes about two days from the time the larva begins eating through the shell until it is entirely out of the latter and into the bean pod.

The young larva begins feeding when the bean is green, and it is well along toward maturity before the bean dries up. The amount of food consumed is small compared with what other insects eat. It appears that the young larva often eats out a short tunnel, advancing a little distance from the point where it entered the bean. When the larva gets larger it eats out a hole somewhat its own shape, and about 50 per cent larger, as is shown in Plate I, figure 3, *a* and *b*.

When the larva reaches maturity, and just before pupating, it eats out a round hole in the cotyledon, directly under the epidermis. The hole is plainly seen through the half-transparent skin or "window," which is broken easily by the adult weevil when it is ready to emerge (see upper beans in Pl. I, fig. 5). The hole is seldom at the spot where the larva entered, but at varying distances from it. The point where the young larva entered, sometimes called the "sting," plainly shows on the dry bean as a dark spot varying in size from a pinpoint to almost as large as a pinhead. This is illustrated in Plate I, figure 2, *a* and *b*.

Mortality among the larvæ after entering the beans is rather high. This is so both in the case where by far more larvæ enter a bean than could develop in it, and in the case where only one or two larvæ enter, although the percentage of mortality is less with the latter than with the former. Table VI graphically illustrates this point:

TABLE VI.—*Comparison of the number of larvæ of Bruchus rufimanus entering beans with the number reaching maturity.*

Number of beans.	Number of larvæ entering beans.	Number of adults.	Maximum number of larvæ entering a bean.	Average number of larvæ entering a bean.	Average number reaching maturity.	Percentage of larvæ entering beans reaching maturity.	Percentage of beans entered by larva.	Percentage of beans infested with adults.
100	263	132	10	2.63	1.32	50.1	85	70
100	199	95	7	1.99	.95	47.7	78	63
100	226	86	16	2.26	.86	38	80	58
100	72	16	9	.72	.16	22.2	40	15
100	54	29	5	.54	.29	53.6	39	26
Average	162.4	71.6	9.4	1.62	.71	42.3	64.4	46.4

It will be seen from the table that although as many as 16 larvæ may enter a single bean, the average number is about 2, and a total average of a little over 40 per cent reach maturity. Comparison with Table IV shows that while a maximum of from 5 to 16 larvæ may enter a bean, the percentage of beans containing more than 2 adults is small.

The larval stage is from 10 to 15 weeks, the average being about 12 weeks.

Immediately after eating out the round hole in the cotyledon, already referred to, the full-grown larva becomes quiet, and in a short time pupates. At first the pupa is the same color as the larva, but gradually turns darker until it is a dark brown.

The pupal stage is from 7 to 16 days with an average of 10 days.

When the adult is first formed it is light brown and very soft, but it gradually turns darker and becomes harder. The adult may soon eat its way out of the bean through the "window" prepared by the larva, or it may remain in the bean for several months. In fact many adults never emerge from the beans at all, but die in them. If the weather is warm, or the beans are handled much, the weevils are apt to emerge from the beans sooner and in greater numbers than if the weather is cool and the beans are not handled much. Many of the adults emerge from the beans after the latter have been planted. The duration of the adult stage varies considerably, depending on the weather conditions, from one month to a possible eight months. Table VII gives a summary of the life-history records.

TABLE VII.—*Life history of the broad-bean weevil in California.*

Locality.	Eggs laid.	Hatched.	Duration of egg stage.	Pupated.	Duration of larva stage.	Adult.	Duration of pupa stage.	Died.	Duration of adult stage.	Total length of life.
	1917.	1917.	*Days.*	1917.	*Days.*	1917.	*Days.*		*Days.*	*Days.*
Pasadena	May 3	May 15	12	Aug. 19	96	Aug. 27	8	Sept. 27, 1917	31	147
Hayward	May 11	May 24	13	Aug. 29	98	Sept. 8	10	Feb. 8, 1918	152	273
Hayward	....	....	......	Sept. 3	......	Sept. 12	9	Dec. 7, 1917	86	......
	1918.	1918.		1918.		1918.				
Alhambra.	Apr. 9	....	......	July 26	......	Aug. 4	10	....	......	......
Alhambra.	...do....	....	......	Aug. 5	......	Aug. 21	16	....	......	......
Alhambra.	...do....	....	......	Aug. 22	......	Aug. 30	8	....	......	......
Alhambra.	Apr. 28	May 5	9	Aug. 5	90	Aug. 12	7	Apr. 23, 1919[1]	253	359
Alhambra.	May 6	May 17	11	...do....	80	...do....	7	Dec. 26, 1918	137	235
Alhambra.	May 7	May 20	13	Aug. 22	94	Aug. 30	8	May 31, 1919[1]	274	393
Alhambra.	Apr. 28	May 7	9	Aug. 12	97	Aug. 28	16	....	......	......
Alhambra.	May 17	May 27	10	Sept. 10	106	Sept. 17	7	....	......	......
Alhambra.	May 17	June 2	16	Aug. 5	64	Aug. 13	8	Dec. 6, 1918	114	203
Alhambra.	May 17	June 4	18	Aug. 30	87	Sept. 13	14	Nov. 30, 1918	78	197
Alhambra.	Mar. 14	Mar. 28	14	....	......	....	......	....	......	......
Averages	....	....	12.5	....	90	....	10	....	140	258

[1] Theoretical, showing possible life history from two records.

SEASONAL HISTORY.

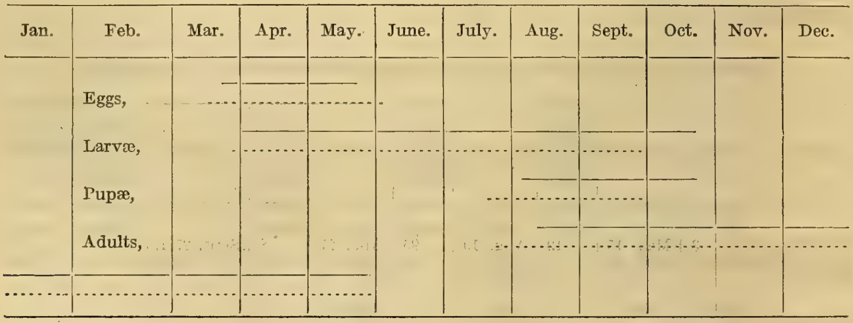
Egg laying begins about the middle of March, is heaviest in April, and extends a little beyond the middle of May. The larval period is from the latter part of March to the middle of October. Pupæ can be found from the first of August to the latter part of October, and adults from the middle of August to about the following June. Tables VIII and IX show the actual records of the seasonal history for 1917 and 1918.

TABLE VIII.—*Seasonal history of Bruchus rufimanus in Pasadena and Alhambra, Calif.*

Year.	First eggs observed.	Last eggs observed.	First eggs hatched.	Last eggs hatched.	First full-grown larvæ.	Last full-grown larvæ.	First pupa.	Last pupa.	First adult.	Last adult.
1917	Mar. 23	May 20	....	....	Aug. 1	Oct. 19	Aug. 3	Oct. 22	Aug. 10	(1)
1918	Mar. 14	May 19	Mar. 28	June 4	July 16	Sept. 26	July 18	Sept. 28	July 25	....

[1] About June 1, 1918.

TABLE IX.—*Graphic chart of life history of Bruchus rufimanus for seasons of 1917–18 and 1918–19.*



Continuous line=1917–18. Broken line=1918–19.

Although a few adults may be found as late as June, the majority die before the end of March. During 1917 a number of badly infested beans were inclosed in a box. Ten per cent of the weevils were dead by February 1, 50 per cent by March, and 90 per cent by the 1st of April. A very few remained alive until June. The results of field observations at Hayward during 1918 as to the prevalence of weevils in the fields are recorded in figure 5. Each count represents an examination of horse-bean plants for a period of 15 minutes.

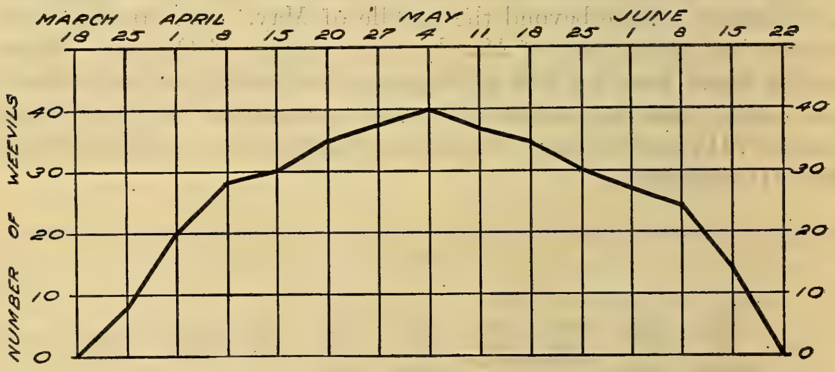


FIG. 5.—Curve showing abundance of broad-bean weevils in a field at Hayward, Calif., 1918.

Adults have never been observed in the field before the latter part of March, but it is evident that some of them must live through the winter, hiding in the soil, or among rubbish, leaves, etc. In experimental plantings of infested beans, both in the fields and in pots, live adults have been observed to come out of the soil several days after planting. In one case a germinating bean was dug up two weeks after it had been planted, and a live weevil, which had emerged from the bean, was found clinging to it. In another germination test, beans were taken from pots 20 days after planting, and a live adult found in one of its burrows in a bean that had germinated.

When disturbed, the weevils have the habit of folding their legs tightly and feigning death. On the plant they will fall to the ground, but quickly become active. In the sack or on a table they are apt to remain quiet, "playing possum" for some time, and it takes quite a prod with a pencil or pin to make them become active.

GERMINATION TESTS OF INFESTED BEANS.

A number of tests were made to determine the effect of weevil infestation on the germinating power of the beans and at the same time compare new seed and that held over a year.

TABLE X.—*Germination tests of infested and noninfested beans; new and year-old seeds.*

Date.	New crop seed, percentage of germination—					Date.	Old crop seed, percentage of germination—				
	With no weevil.	With 1 weevil.	With 2 weevils.	With 3 weevils.	With 4 and 5 weevils.		With no weevil.	With 1 weevil.	With 2 weevils.	With 3 weevils.	With 4 and 5 weevils.
Apr. 26, 1916	98	90	60	72	......	Oct. 27, 1916	96	94	86	88	......
Nov. 20, 1916	98	92	68	98	......	Nov. 20, 1916	100	90	90	90	75
Dec. 1, 1916	96	94	86	88	......	Dec. 1, 1916	90	70	90	90	......
Dec. 13, 1916	86	60	54	50	......	Dec. 13, 1916	88	64	56	......	......
May 8, 1916	100	100	92	92	87	Mar. 22, 1918	84	72	80	24	44
Mar. 22, 1918	92	88	88	73	......	Oct. 17, 1918	100	38	54	8	......
Oct. 17, 1918	98	68	26	28	52						
Apr. 28, 1916	98	90	88	68	70						
Average	95.7	82.7	72.7	71.1	69.6	Average	93	71.1	76	60	59
Average of infested beans					74	Average of infested beans					66

This table shows that as the number of insects per bean increases, the percentage of germination decreases. The drop is about 20 per cent from perfect beans to those infested with one weevil, and somewhat less for each weevil up to the maximum of 4 and 5 weevils, which gives a germination of 60 or 70 per cent. The table also shows that the percentage of germination is a little more with new crop seeds than with those held over for a year.

The table, however, does not show the reason for the low germination in the infested beans. In only a few cases does the insect actually injure the embryo or germ, but by far the greatest damage comes from the fact that the holes made by the insects allow bacteria or fungi to enter, which cause the beans to rot. In a number of cases rotting takes place soon enough to prevent germination entirely, but a large number of beans are killed also after the seed has actually germinated, and before the shoot can get out of the ground. Rotting of the seed is much worse during cool or cold weather, when germination is slow, than during warm weather, when germination takes only a few days. One germination experiment had to be discarded, as rotting of the seed was practically 100 per cent. In another test, the soil was sterilized with formalin, and germination was perfect, not only with uninjured beans, but also with those having 1, 2, and 3 weevils in them. Those having 4 and 5 weevils gave a 92 per cent germination, the balance being injured in, or too close to, the germ.

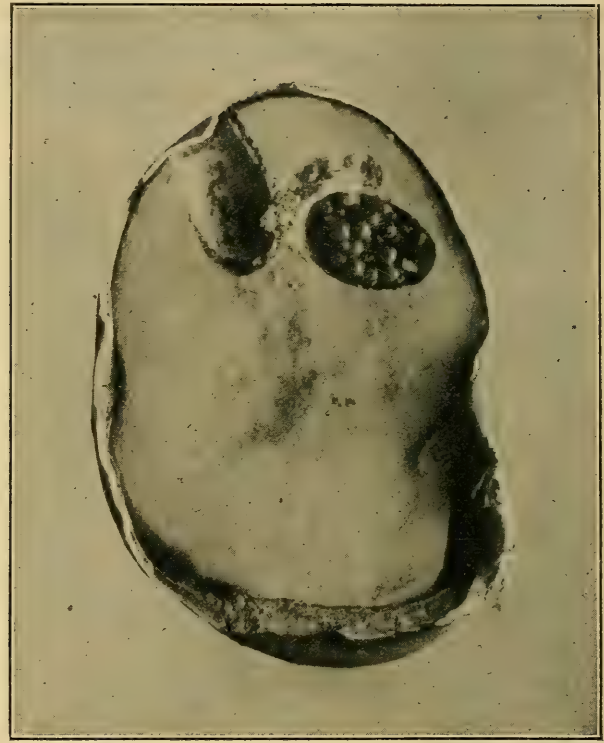


FIG. 6.—Broad bean cut in half to show pupal cell of the broad-bean weevil containing predacious mite (*Pediculoides ventricosus*). Enlarged. (Chittenden.)

Whether infested beans produce weak plants or small crops, was not determined, but it was observed many times that the sprouts from infested beans were much less vigorous than those from perfect beans.

NATURAL ENEMIES.

The only natural enemy of *Bruchus rufimanus* observed during the investigation was a predacious mite, *Pediculoides ventricosus* Newport (fig. 6). This was observed a number of times, but only a small fraction of 1 per cent of the insects were affected. Mr. W. B. Parker reports having observed a beetle in the clutches of the ruduviid bug *Zelus renardii* Kolen. Several hymenopterous parasites[1] are recorded by European writers, but have not been observed in this country.

CONTROL MEASURES.

It is obviously impossible, at least from a practical standpoint, to prevent infestation of the beans in the field by such methods as the application of poisons or deterrents. Any control measures, therefore, must be toward keeping the adults from getting into the fields, or, in other words, must consist of planting seed which contains no live weevils.

Mr. W. B. Parker reports good success in treating infested beans with water heated to about 150° F. (160° and over affects germination) for from 15 to 20 minutes. This might do for small gardens, but is obviously impractical for commercial plantings.

DRY HEAT.

A series of experiments was carried on to determine the degree of heat and the length of time required to kill the weevils. Preliminary experiments showed that exposing infested beans to from 120° to 160° F. for from 5 to 40 minutes did not kill all the weevils. Following is the result of the final experiment. Heat was supplied by electricity. For each test a sack of about 2 pounds of beans was used in a fumigating box with a capacity of 60 cubic feet. Later the beans were carefully examined to find whether they contained live or dead weevils.

TABLE XI.—*Effect of dry heat on the broad-bean weevil.*

Date treated.	Date examined.	° F.	Time treated.	Result.
1917.	1918.		*Minutes.*	
Nov. 15	Mar. 28	160	30	Some alive.
Oct. 24	do	160	40	Do.
Oct. 20	do	160	40	Do.
Nov. 15	do	170	20	Do.
Oct. 24	Mar. 5	170	20	Do.
Do	Mar. 28	170	25	All dead.
Oct. 20	do	170	30	Do.
Nov. 15	do	170	30	Some alive.
Oct. 20	Mar. 5	170	40	All dead.
Nov. 15	Mar. 28	180	15	Some alive.
Do	Mar. 5	180	20	All dead.
Aug. 24	Mar. 28	180	20	Some alive.
Sept. 19	do	180	30	Do.
Oct. 24	Feb. 27	180	30	All dead.
Oct. 20	Mar. 28	180	40	Do.

These experiments indicate that dry heat is not a satisfactory remedy for the broad-bean weevil, because in order to be effective it has to be so high that the germinating power of the beans may be destroyed. The experiments were carried on mostly in the fall, shortly after all the adults had formed. Other experiments during the spring, toward the end of the life of most of the weevils, gave a complete killing with a lower degree of heat and a shorter time.

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[1] *Sigalphus pallipes* Nees, *Sigalphus thoracicus* Curt., *Chremylus rubiginosus* Nees (1, p. 57).

Treatment of from 125° to 145° F. for several hours, as recommended for bean and pea weevils in a recent Farmers' Bulletin (7), was not tried. Experiments indicated, however, that the horse-bean weevil is more difficult to kill than the ordinary bean weevil. Unless the heat can be easily controlled and not allowed to go much above 145°, other remedies will be much safer to use.

FUMIGATION.

Sulphur was first tried, using varying strengths up to 2 pounds to 100 cubic feet of space for a period of 3 hours, and proved unsuccessful.

The standard remedy for bean weevils, carbon disulphid, was next tried. The experiments were arranged to compare the effect of infested beans fumigated while the insects were in the immature stages and after all had reached the adult stage. Examination of beans during the experiment gave the following results:

TABLE XII.—*Development of Bruchus rufimanus Aug. 15 and 17, 1918, at Alhambra, Calif.*

	Per cent.
One-half to three-fourths grown larvæ	37.6
Full grown larvæ	20.9
Total larvæ	58.5
Pupæ	20.
Adults	21.5

TABLE XIII.—*Effect of carbon disulphid on the broad-bean weevil.*

Pounds CS_2 per 1,000 cubic feet.	Percentage of beans with all weevils dead.			
	Exposed 18 hours.		Exposed 24 hours.	
	Treated in August.	Treated in October.	Treated in August.	Treated in October.
Check, not treated	43	14	43	14
2	55		52	
3	55		52	
4	69	83	60	81
5	70	94	82	96
6	60	90	62	99
7	74	100	79	100
8		99		100
9, 10, 12, 15, 20		100		100

Conclusions from the carbon disulphid fumigation experiments:

1. Exposure in October when the insects were in the adult stage gave a 20 per cent better result than in August, when they were in the larval stage.

2. A 24-hour exposure gave only about 2 per cent better results than one of 18 hours.

3. A 48-hour exposure gave about a 5 per cent better result than one of 24 hours.

4. Seven pounds to 1,000 cubic feet for 24 hours was the least amount to give a 100 per cent killing.

5. Germination is not affected by the treatment, as beans treated with 15 and 20 pounds per 1,000 feet for 24 hours gave 95 and 97 per cent germination.

Contrary to expectations, it was found that fumigating while the insects were in the larval stage was less effective than in the adult stage. A glance at Table XII will show that when the first fumigation took place in August, almost 40 per cent of the larvæ were not full grown. These were still eating within the bean, and had not come up to the epidermis and formed the "window" through which the adult emerges. It is evident, therefore, that the gas can not penetrate into the interior of the beans to the partially grown larvæ as easily as it can reach the full-grown larvæ, pupæ, or adults directly under the skin.

It was further observed that in the beans fumigated in August a number of full-grown larvæ and pupæ had been killed.

Lengthening the time of exposure did not greatly increase the percentage killed. This conforms to the opinions of Dr. W. E. Hinds (6) of the Alabama Experiment Station, who says, "As a matter of fact, most, if not all, of the killing will have occurred during the first 6 hours of the exposure, and the building may be ventilated after that time, as a minimum, has elapsed, although it is better to wait 12 hours or longer." On the effect of carbon disulphid on the germination of the seeds, Dr. Hinds states: "It would appear from numerous tests that there is practically no danger of injuring germination in treating seeds that are well matured and dried out before treatment is given. *It would not be wise to treat moist seeds, or planting seed of any kind, during periods of very humid atmosphere*, as the seeds might take up enough moisture to make them liable to injury from the vapor."

HOLDING OVER SEED.

Life-history studies showed that the horse-bean weevil had but one generation a year, that it did not breed in the dry beans, and that the last few remaining live adults died by the 1st of July. By merely holding the beans over, therefore, until the second year, they will be uninfested as far as live weevils are concerned. The beans should be stored in sacks or containers tight enough to prevent any live weevils getting out during the first season.

By referring to Table X, it will be seen that the germination of old seed is only slightly less than that of new seed.

Mr. Ronald McKee, in his bulletin on horse beans (8) previously mentioned, states: "Horse-bean seed retains its vitality for a number of years. * * * Germination tests of seed 4 years old of a number of varieties grown at Chico, Calif., showed little or no deterioration."

It can not be emphasized too strongly that any control measures to prevent weevil infestation should be undertaken by the entire community and not by a few growers. If all growers in the horse-bean districts would plant either absolutely uninfested beans, seed which had been given a thorough treatment with carbon disulphid, or seed which had been held over until the second year, the resulting crop would be of a very much higher quality as regards freedom from weevil infestation.

LATE PLANTING.

It has been observed for some time by horse-bean growers and buyers that the crops from seed planted early in the season were likely to be infested more badly than those from seed planted later. In administering the Food and Drugs Act, inspectors of the Federal Bureau of Chemistry collected samples of horse beans from all parts of the State, and ascertained for each sample the time of planting and the percentage of infestation. From the data furnished by them, and from samples taken and tested by the writer, the following tables were compiled. In Table XIV the growers did not know the exact date of planting, but remembered only whether they were planted early or late.

TABLE XIV.—*Comparing the degree of weevil infestation in crops planted early and late. Data from all horse bean districts in California.*

Year.	Planted early.[1]		Planted "later."		Planted late.	
	Number of sacks.	Percentage of infestation.	Number of sacks.	Percentage of infestation.	Number of sacks.	Percentage of infestation.
1916	17,100	32.5	....	....	5,380	6.3
1917	1,500	34.3	1,990	18.77	1,960	6.5

[1] Early means previous to January 1; late, subsequent to March 1.

Whenever possible, the month of planting the seed was ascertained in connection with the degree of infestation, and these data are given in Table XV.

TABLE XV.—*Comparing the degree of weevil infestation in horse beans from all districts in California, planted in different months.*

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1916	46	47	15.2	14.4	5.2	9.6	1	0
1917	....	50	15.6	17.5	8.21	12	....	....
1918	....	30.1	19.1	18.5	15.7	12.9	4.3	.8
Average	....	42.3	16.6	16.7	9.7	11.5	2.6	.4

To test this out further, plantings of horse beans were made at Pasadena, Alhambra, and Hayward, for the years 1917 and 1918, in which a certain number of beans were planted each month, and when harvested carefully examined to find out the percentage of infestation. The results are given in Tables XVI and XVII.

TABLE XVI.—*Showing the percentage of weevil infestation of beans planted during certain months at Pasadena and Alhambra.*

Year.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.
1917[1]	....	17	11.5	12	7.5	5	2.6
1918	43.5	45	15.5	8	.75	....	....

[1] Degree of infestation for 1917 crop found by counting larval entrance holes, which are about 50 per cent greater than number of adult weevils.

TABLE XVII.—*Showing the percentage of infestation of beans planted during certain months at Hayward, Calif.*

Year.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.
1917	....	....	....	24	18	9.6	9.3
1918	74.5	67.5	32	14	5	....	....

These tables clearly show that the later in the season the seed is planted the lower the percentage of infestation will be. A possible explanation of this may be found by referring to the seasonal history of the insect, which shows that egg laying begins about the middle of March, is heaviest in April, and extends to the middle of May. Figure 5 shows also that at Hayward the first adults were observed in a broad-bean field on March 18 and that the number constantly increased each week to May 4, after which the number decreased as constantly until June 15, the last date any were observed. Since the eggs are laid only on the pods, it follows that any plants which produced pods prior to or during April will be subject to the greatest egg deposition, and pods produced subsequently to the latter part of April would be liable to little or no egg deposition.

Seed planted from October to February begins setting pods in March and April, while seed planted from the latter part of February to May will begin setting pods from the latter part of April to June.

It would seem, therefore, from consulting the tables giving the percentages of infestation for seed planted in different months, from the insect's life history, and from the rate of growth and pod setting by the plant, that whenever possible it will be advisable to delay the planting until from the latter part of February or the first of March to May. A glance at Tables XIV and XVII will show that plantings prior to February and March show much higher percentages of infestation than those planted subsequently.

This contention is further borne out in the experience of the Oceano-Morro district in San Luis Obispo County. It was the custom there to begin planting about November, continuing all winter and spring. For several years the horse beans had been seriously infested with the bean aphis (*Aphis rumicis* L.) which also did severe damage to the later planted crops of small white and pink beans. Assuming that the early planted horse beans acted as a winter host for the bean aphis, propagating it in great numbers before the more extensive plantings of other beans were made, the horticultural commissioner persuaded all horse-bean growers to delay planting in the 1917–18 season until March 1. This agreement was adhered to with a few minor exceptions, and the result is shown in Table III. The maximum and average percentages of infestation for the Oceano-Morro district for 1916 are 50 and 14.5 per cent and for 1917, 63 and 14.5 per cent. In both these years a good share of the crop was from seed planted early, that is, from November to March, but in 1918, when practically no seed was planted until after March 1, the maximum and average per cent of weevil infestations are 17.2 and 2.92, a reduction of over 75 per cent. The majority of the plantings were not infested at all, particularly those which had been planted in April and May.

The planting season begins soon after the first rains, or ordinarily in October and November, in some sections, while in others it is delayed until spring. The former are the drier inland sections where the crop must be matured before the warm dry weather of the early summer, and the latter are the low, cooler, coastal valleys where the summer heat is not high enough to affect the crop.

The earlier plantings, especially in the dryer sections, usually produce larger crops than late plantings. This is particularly true where the beans are raised without irrigation. The climate and soil conditions, therefore, as well as the availability of irrigation water, must be taken into consideration in arranging for a delayed planting program. Where late planting can not be practiced because of these conditions, it is especially important that all seed either be uninfested or treated to kill the weevil before planting; but where conditions are favorable, planting should be delayed as late as is commensurate with getting a good crop.

RECOMMENDATIONS.

Only uninfested or treated horse beans should be used for seed. All horse beans used for seed which are infested with the broad-bean weevil either should be treated with carbon disulphid or held over in tight receptacles until the second year, when the weevils will all be dead.

Carbon disulphid should be used at from 7 to 10 pounds per 1,000 cubic feet, for at least 24 hours, in a box, barrel, or room as air-tight as it is possible to get. The smaller amount is effective in perfectly tight receptacles, but the larger amount should be used if the fumigating box or room is not tight. The liquid should be placed in a shallow pan at the top of the box or poured over the seed.

Infested seed which has not been treated and is held in warehouses or barns near broad-bean fields, except that held over for seed until the second year in tight receptacles, should be disposed of or fed before the planting season.

Badly infested seed should be ground up in feed mills immediately after harvesting.

Planting should be delayed until as late as possible, preferably after March 1. In the dryer and hotter localities where this is not possible, it is especially important to plant only seed which is uninfested or has been treated to kill the weevil.

All growers of horse beans should cooperate in carrying out these measures.

SUMMARY.

Broad-bean growing has been handicapped seriously by the presence of the broad-bean weevil (*Bruchus rufimanus*).

Although the first record of this insect's establishment in America was in 1909, it probably has been here since about 1888.

It is found in the entire broad-bean section of California.

The weevil not only lowers the value of the beans but has greatly reduced the acreage planted to that crop.

The insect has but one generation a year and does not breed in dry beans.

The egg stage is from 9 to 18 days; the larval stage, 10 to 15 weeks; the pupal stage, 7 to 16 days; and the adult stage, 1 to 8 months.

Eggs are laid on the green bean pods in the field from the middle of March to the middle of May; the larvæ reach maturity from August to October, while adults can be found from August to the following June.

Germination of infested beans is from 20 to 40 per cent less than that of uninfested beans.

Germination of seed a year or more old is only slightly less than that of new seed.

There are no natural enemies of the broad-bean weevil of any consequence in America.

It requires 170° to 180° F. for over half an hour to kill all of the weevils in broad beans.

Sulphur is unsatisfactory as a fumigant.

Carbon disulphid at the rate of 7 pounds per 1,000 cubic feet in a tight box for 24 hours kills all the weevils.

In seed held over until the second year all the weevils are dead.

Beans from crops planted late, after March 1, are much less infested than those planted earlier, from November to March.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 808

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER February 24, 1920

STUDIES ON THE LIFE HISTORY AND HABITS OF THE JOINTWORM FLIES OF THE GENUS HARMOLITA (ISOSOMA), WITH RECOMMENDATIONS FOR CONTROL.[1]

By W. J. Phillips,
Entomological Assistant, Cereal and Forage Insect Investigations.

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INTRODUCTION.

Owing to the chaotic condition existing until recently in the classification of the genus Harmolita (Isosoma), it has been practically impossible to obtain specific determinations, and this fact has largely prevented economic workers from undertaking detailed life-history studies of the various species. Some members of this genus are of great economic importance, the losses directly traceable to them running into the millions of dollars every year. Despite this fact very little has been known concerning the identity and habits of the species which cause these losses. For example, it was not known definitely whether *Harmolita tritici* Fitch, the most important member of the genus, had a dozen host plants or whether it was confined to wheat alone. The object of this paper, therefore, is to place on record in as brief a manner as possible the main facts, in so far as they have been developed, in the life histories of the species that have been studied thus far, and to propose a basis for control.

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[1] The writer wishes to acknowledge his indebtedness to various members of the branch of Cereal and Forage Insect Investigations who furnished material from time to time for breeding work, but more particularly to Messrs. W. T. Emery, Philip Luginbill, and T. H. Parks, and to Dr. Henry Fox, who have been associated with him and have rendered valuable assistance in breeding, and to Mr. A. B. Gahan for kindly criticisms of the manuscripts.

The species infesting the grain crops will be considered first, then those affecting the cultivated grasses, and lastly the species living in wild grasses. Nearly every species is of either direct or indirect economic importance. Those affecting the grain crops and the cultivated grasses are obviously of direct economic importance because of the very considerable losses entailed by their depredations or their potential capacity for injury. The importance of the different species varies greatly since the damage inflicted by some is far greater than that caused by others. The economic aspect of those species affecting wild grasses is less obvious. They do not cause a loss to the farmer, but on the contrary probably are an advantage to him, since they serve as intermediate hosts for the many parasitic insects which play such an important rôle in the natural control of the species infesting cultivated crops. Without these intermediate hosts it is doubtful whether some of the parasites would be able to maintain themselves under the abnormal conditions created by cultivation. The more important species of parasites are common to the majority of species of Harmolita, however, and consequently are able to survive those periods during which there is a lack of hosts breeding in cultivated crops, by turning their attention to related species breeding in wild grasses.

It is difficult to estimate the value of jointworm parasites in terms of dollars and cents to the wheat-growing regions east of the Mississippi River. The writer is convinced, however, that farmers would have been obliged to resort to artificial measures of control for the wheat jointworm years ago had it not been for the efficiency of these parasites. The parasites of the jointworms will be treated in a paper to be published subsequently.

SPECIES INFESTING THE GRAIN CROPS.

THE WHEAT JOINTWORM.[1]

Harmolita tritici probably is the most important species in the whole genus, since it causes very serious losses in nearly all the wheat-producing States east of the Mississippi River and in a large part of

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[1] *Harmolita tritici* Fitch.

Missouri. It has been known as a serious wheat pest since 1848 and it is strange that it has not extended its range into the great wheat-producing States of Texas, Oklahoma, Kansas, Nebraska, the Dakotas, and farther west. At present no satisfactory explanation of this fact can be offered, although the species undoubtedly will invade that part of the country sooner or later. *Harmolita tritici* has been confused in literature with *H. hordei*, *H. secalis*, *H. captiva*, *H. vaginicola*, *H. elymicola*, and doubtless with others. It was first described by Asa Fitch (3)[1] in 1859 as *Eurytoma tritici* and was subsequently described under several names by various authors. Entomologists disagreed for years regarding this species before the phytophagous habits were definitely established.

MANNER OF INJURY.

A plant infested by the wheat jointworm may not show any external signs of infestation whatever, or the stems may be distorted and have wartlike elevations on them (Pl. II, C). In any case the stem at the point infested is hard and woody and where there is no distortion the point of infestation may be readily detected by pinching the stem between the thumb and forefinger. These infested places usually occur above the second or third joint from the root but may occur above any joint. In badly infested fields several joints may be affected and a large number of plants may fall (Pl. I, B), thus greatly reducing the yield. It is not necessary, however, that the plants fall or lodge to reduce the yield greatly. The writer has taken heads from healthy and from infested stems, carefully measured them against one another, and has found that the grain of the infested plants from the same number of heads of exactly the same length as the uninfested were very much lighter and of much smaller volume (Pl. I, A).

When plants lodge or fall to a considerable extent the yield is far more reduced than when the plants remain standing. In the first place, the plants that fall, in nearly every case, will escape the binder. Should the binder reach them they will be bound so near the butt of the bundle that most of them will fall out with subsequent handling. Could they be bound securely the yield would scarcely be 50 per cent as large as that from heads of equal length taken from normal plants. The grains, moreover, are small and somewhat shriveled. The inferior grain seems to be due to improper nourishment during the growing period. The young larvæ develop in the walls of the stem and disarrange the fibro-vascular bundles, thus greatly weakening the stem at this point. A storm, light rain, or heavy wind will cause the plant to bend over at the point of infestation, as the plants are thus made much more top-heavy. As the growing larvæ consume proportionately large amounts of sap, the developing wheat kernels are constantly robbed of their nourishment and suffer accordingly.

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[1] Numbers in parentheses refer to "Literature cited," p. 26.

A field of wheat badly straw-fallen usually is attributed to the depredations of the Hessian fly by the average farmer, and very often the fly is wrongly credited year after year, in the States east of the Mississippi River, with serious and widespread injury that is chargeable to the jointworm.

HOST PLANTS.

During repeated trials covering a number of years this species was never induced to breed in any plant but wheat. It never has even been observed to attempt oviposition in any other plant. The stems of barley and rye particularly do not differ greatly from wheat, but they seem to be distasteful to *tritici*.

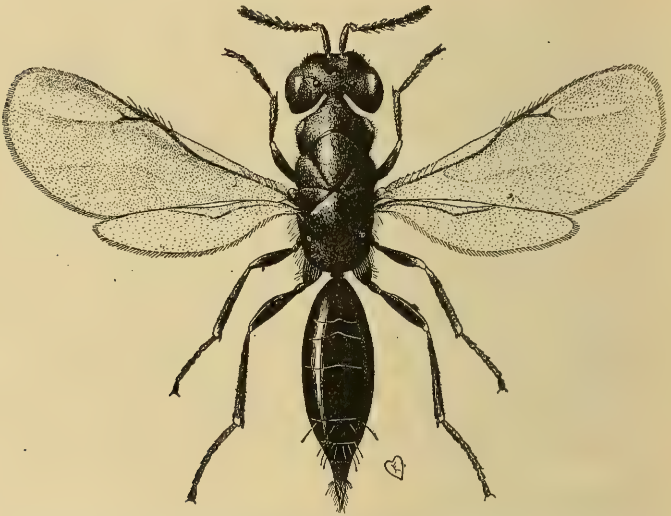
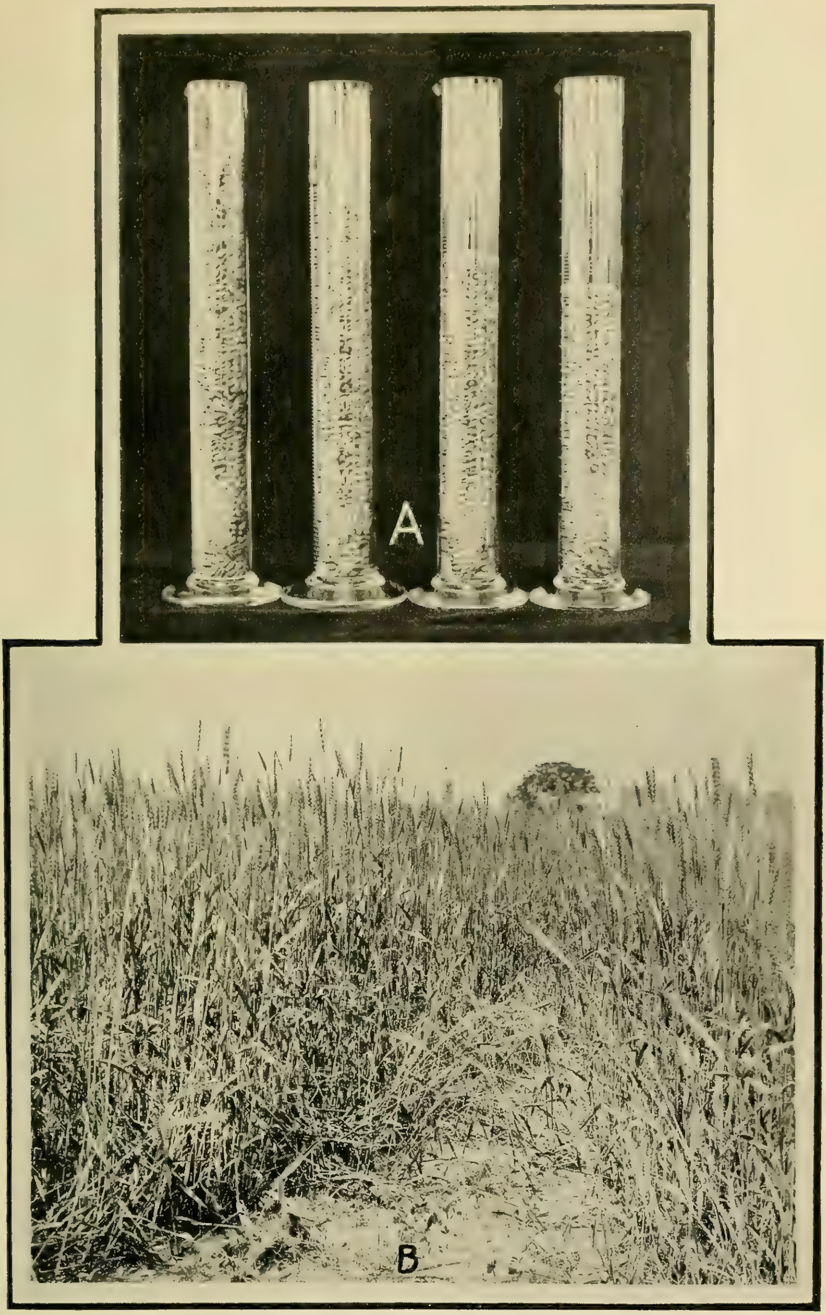


FIG. 1.—The wheat jointworm (*Harmolita tritici*): Adult female. Greatly enlarged. (The head is tilted back somewhat so as to show the groove in front.) (Author's illustration.)

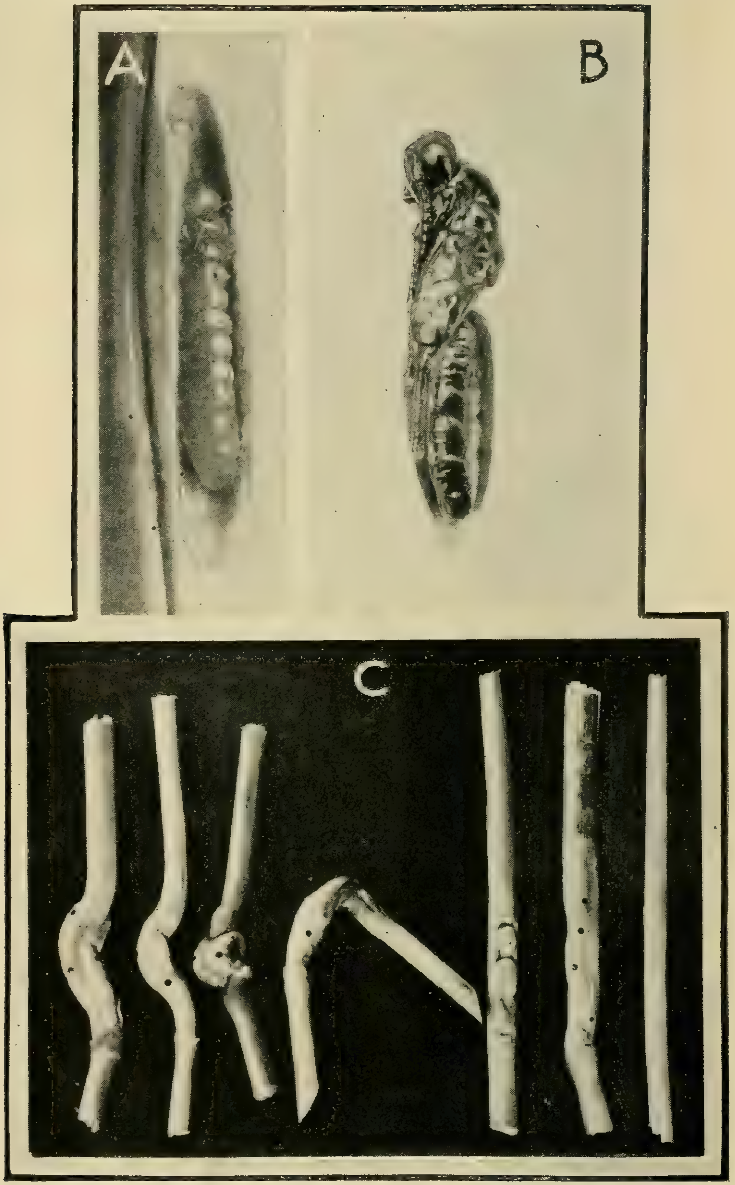
LIFE HISTORY.

There is only one generation a year. The adults (fig. 1) emerge in May and deposit their eggs in the stems of growing wheat just about the time the heads begin to appear. The life of adults lasts from a few days to a week or more, depending upon the temperature. The eggs (fig. 2, *a*, *b*) hatch in about 10 days. The larvæ mature in



JOINTWORM FLIES OF THE GENUS HARMOLITA.

A, Comparative yields from healthy wheat plants and those infested with the jointworm (*Harmolita tritici*); reading from left to right, the yield from 85 uninfested stems, 85 stems with one node infested, 85 stems with two nodes infested, and 85 infested fallen straws. The heads were all measured against each other, so that, for example, any head from the lot of uninfested plants had a corresponding head of equal length in all the infested lots; B, Field badly infested with the jointworm. Note the large percentage of fallen straws.



JOINTWORM FLIES OF THE GENUS HARMOLITA.

H. tritici: A, Cell with the top lifted off exposing the larva (greatly enlarged); B, pupa (greatly enlarged); C, characteristic galls (about natural size).

about three weeks or a month from date of oviposition. They molt at least three times and possibly four. The larvæ (Pl. II, A) are yellow, footless grubs, three-sixteenths of an inch long at maturity. They remain in the larval stage until late fall or early winter, when the majority usually change to pupæ (Pl. II, B), the remainder pupating very early in the spring.

Males normally occur, although in confinement this species will breed parthenogenetically, in which case the progeny are all males.

THE WHEAT STRAW-WORM.[1]

Harmolita grandis ranks next to the wheat jointworm in importance as an enemy of wheat. Were it not for the ease with which it can be controlled it probably would be more destructive, and might even command greater prominence than the Hessian fly, due to the fact that there are two generations a year. At any rate, it is at present the most important of the jointworm group west of the Mississippi River, where it often causes widespread injury. *H. grandis* is probably the most widely distributed species in the United States, occurring usually in greater or less numbers wherever wheat is grown. Though occurring in

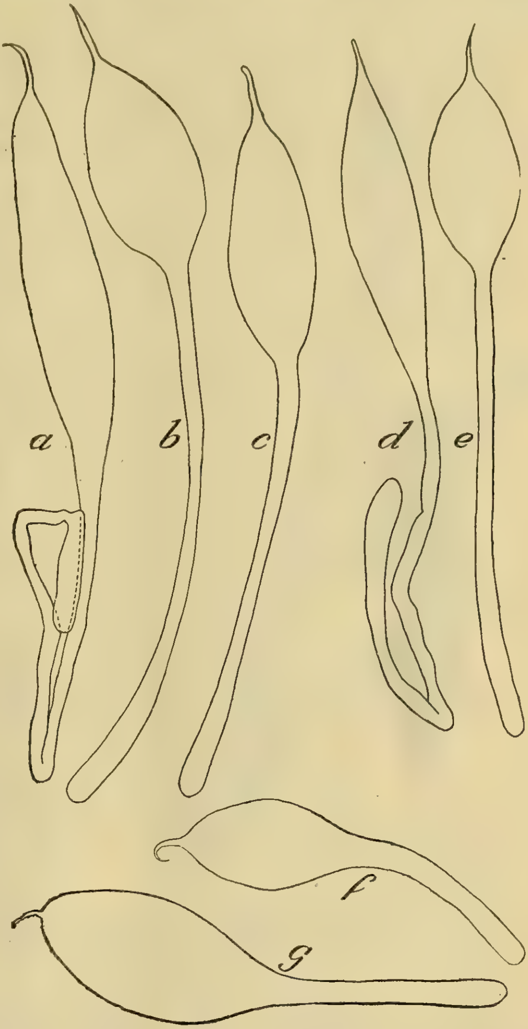


FIG. 2.—Eggs of species of Harmolita: *a*, *H. tritici*, after oviposition; *b*, *H. tritici*, before oviposition; *c*, *H. elymivora*, before oviposition; *d*, *H. hordei*, after oviposition; *e*, *H. hordei*, before oviposition; *f*, *H. grandis*, form *minuta*; *g*, *H. agropyrophila*. All greatly enlarged. (Original.)

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[1] *Harmolita grandis* Riley.

practically every wheat-growing section east of the Mississippi River, it rarely has caused any serious losses in recent years, although it exacts a small toll annually. This possibly may be explained by the fact that wheat fields in the Eastern States are located usually at a distance from the old stubble fields of the previous year, and since the spring generation is wingless, only a small percentage of the individuals is able to make the journey safely from one wheat field to another, and it thus becomes difficult for the species to maintain itself.

H. grandis is a comparatively old offender, but probably has escaped being confused with other species, as it has some rather striking characters, though the fact that it is dimorphic greatly perplexed all entomologists for a number of years. Each form was considered and described as a separate and distinct species. Riley (11) described the spring form as *Isosoma tritici* in 1882, since he considered Fitch's *tritici* as a synonym of *hordei* Harris. In 1884 the late F. M. Webster established the dimorphic habits of *grandis*, rearing both forms, and Riley (12) described the summer form as *Isosoma grande.* In 1896 Howard (8, p. 10) definitely established Fitch's *tritici* as a valid species and gave the name *minutum* to the vernal generation of Riley's species previously referred to in literature as *tritici*. *H. grandis* is probably the most interesting species of the whole group. There is one other species that has two generations during the year, but no others, so far as is known, are dimorphic.

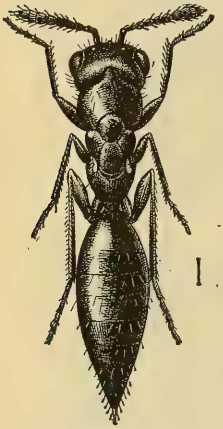
FIG. 3.—Wheat strawworm : Wingless adult female of spring form (*Harmolita grandis*, form *minuta*). Greatly enlarged. (Webster and Reeves.)

HOST PLANTS.

The writer has never succeeded in rearing *H. grandis* from any plant but wheat. He has observed it oviposit in other plants but no larvæ were ever found in them. Further experiments along this line may disclose other hosts. As it is found in sections where very little wheat is grown consecutively, it seems as though there must be at least one other host.

LIFE HISTORY AND MANNER OF INJURY.

The spring form (fig. 3) (*H. grandis*, form *minuta*) attacks the wheat plants when they are small (fig. 4), the eggs (fig. 2, *f*) being deposited in the base of the young plant. The developing larva totally destroys the tiller affected, and if the plant has not tillered it kills the entire plant. The larva develops within and right at the base of the plant, usually making the plant somewhat bulblike at this point (fig. 5). This generation emerges during March and April in the Eastern and Central States, while in Washington and probably in other Pacific States it emerges in April. This spring generation usually is wingless, though occasionally specimens may have wings. These winged individuals usually are imperfect in that they often have only two or three wings. Sometimes only the front pair are present, and again only the hind wings. Males occasionally occur in this generation, though rarely.

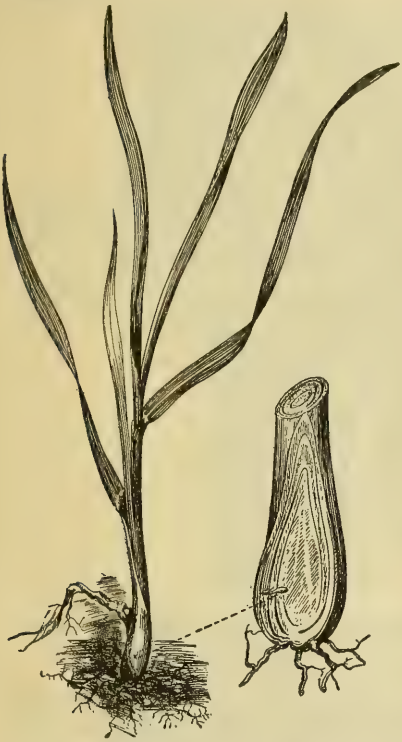

Fig. 4.—Wheat straw-worm: Stage of development of wheat plant at time of oviposition of spring form (*Harmolita grandis*, form *minuta*). Enlarged illustration at right shows the point where egg is deposited. (Webster and Reeves.)

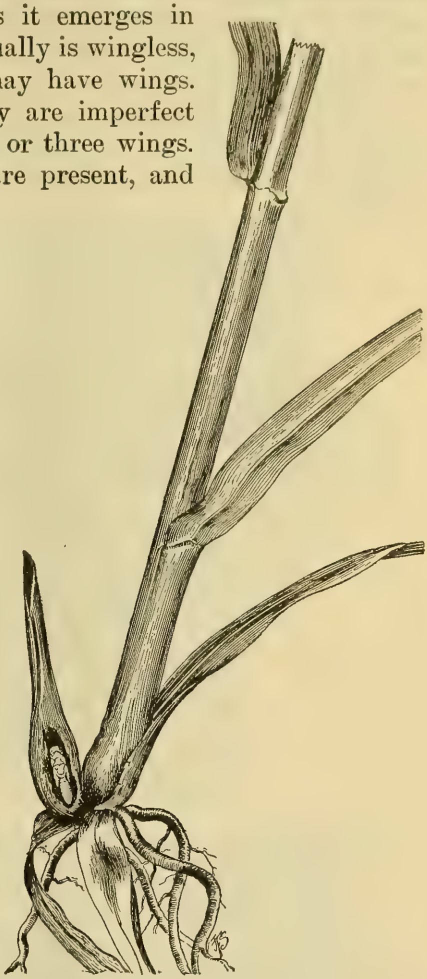

Fig. 5.—Wheat straw-worm: Pupa of summer form (*Harmolita grandis*, form *grandis*) as it normally occurs in the field. The tiller thus attacked is always killed. (Webster and Reeves.)

The summer form (fig. 6) (*H. grandis*, form *grandis*) emerges in May and deposits eggs (fig. 7, *d*, *e*) in the growing wheat plants slightly above the joints, often placing the eggs directly in the cavity of the stem, where they hatch in about 5 days. Sometimes they are placed in the walls. Several eggs are placed occasionally in the same joint but the writer never has found more than one full-grown larva at a joint, the others apparently being killed by the surviving larva. The larva rasps the inner walls of the stem, sucks the juices, and subsequently forms a neat little cell within the joint (Pl. IV, B). In all the winter wheat areas the effect upon the plant is to cut down the yield of grain, while in places where both spring and winter wheat are sown, often in adjoining fields, the summer form turns its attention to the spring wheat in preference to the older and tougher plants of the winter wheat. Spring wheat is affected very much in the same manner as winter wheat is injured by the first generation (form *minuta*). The summer generation remains in the old wheat stubble, pupating in the fall. The spring generation, as previously stated, emerges in March and April. The writer has never seen males of the summer generation.

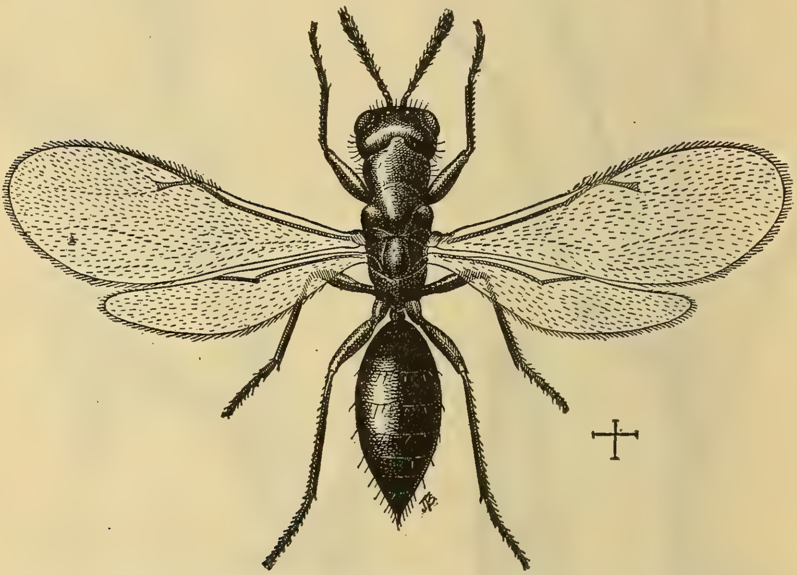

FIG. 6.—Wheat straw-worm: Adult female of summer form (*Harmolita grandis*, form *grandis*.) Greatly enlarged. (Webster and Reeves.)

THE WHEAT SHEATH-GALL JOINTWORM.[1]

Harmolita vaginicola was not described until 1916 (2), though the typical form of its injury to wheat was recorded in literature many years ago. There are specimens in the National Museum collection that bear the manuscript name *Pteromalus hordei* Harris, which were collected in Virginia in the early fifties, and some that

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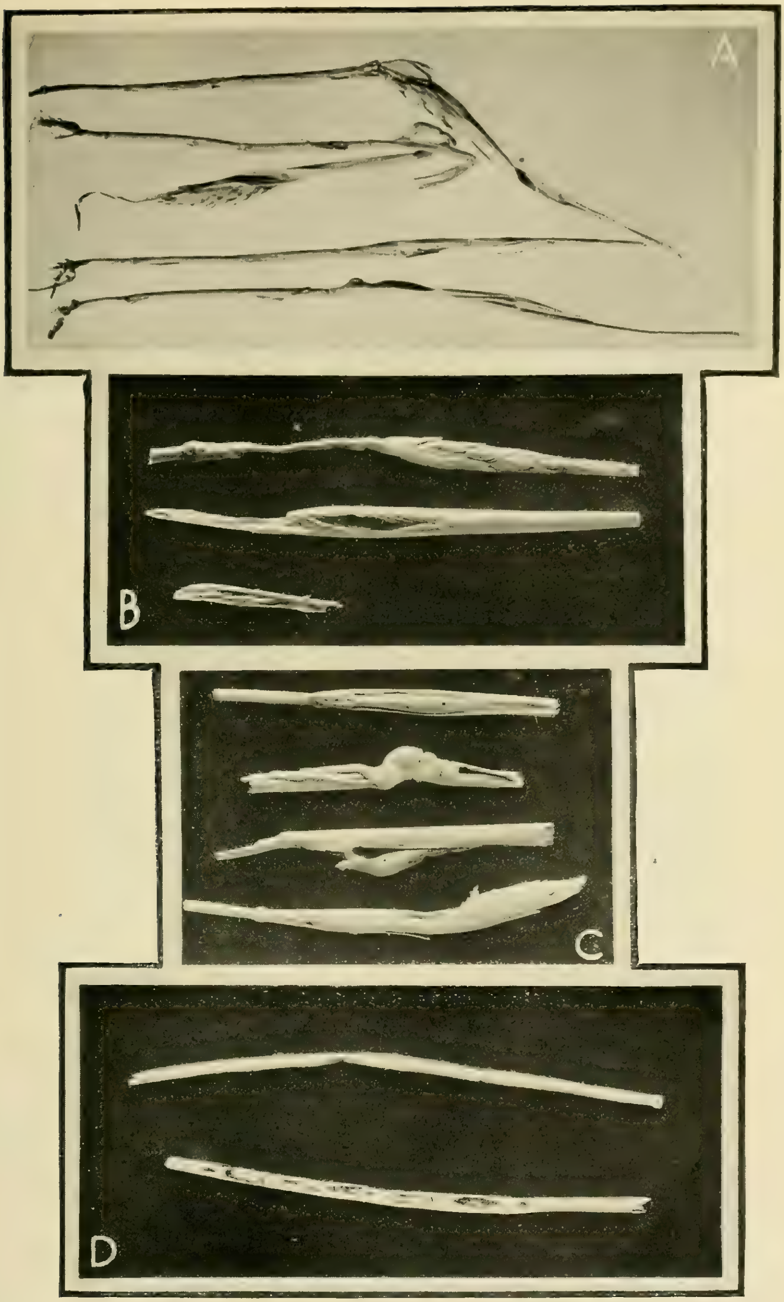
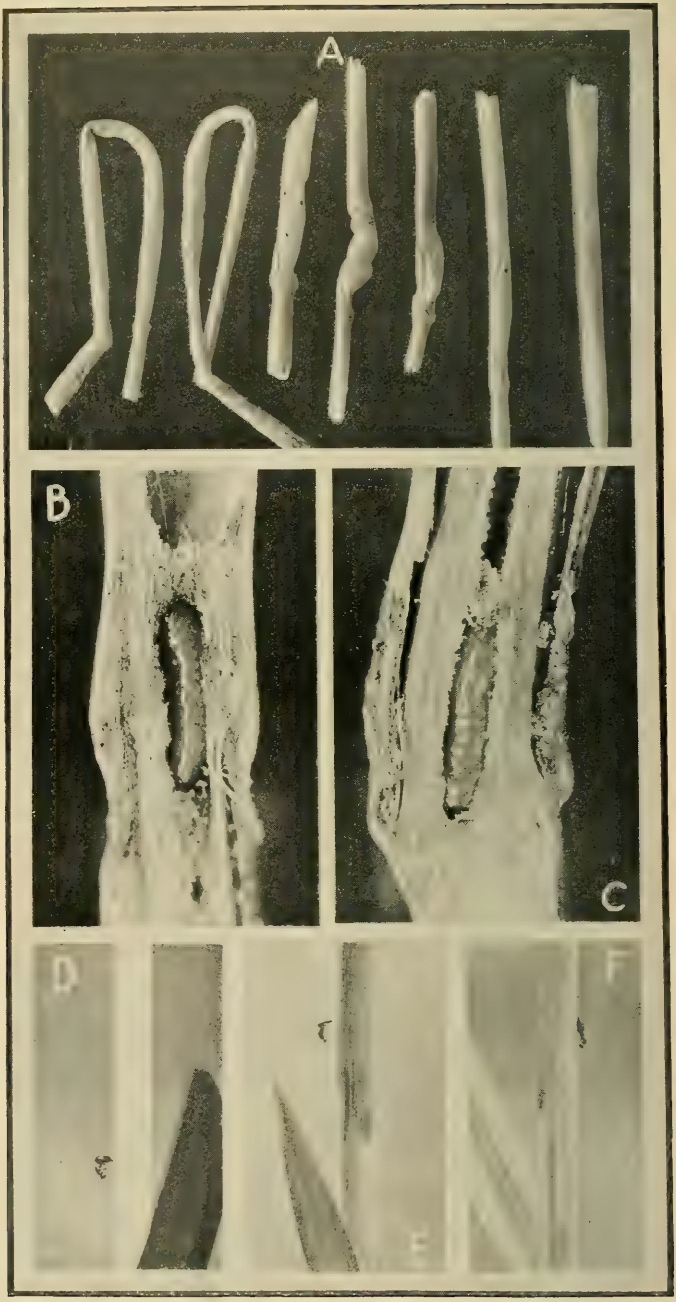
[1] *H. vaginicola* Doane.



JOINTWORM FLIES OF THE GENUS HARMOLITA.

A, Characteristic manner in which *H. vaginicola* dwarfs wheat plants. These plants rarely form grain. About one-third natural size; B, Head from a plant dwarfed by *H. vaginicola* with the surrounding leaf sheath removed, showing the galls in the sheath and not in the stem. Slightly reduced; C, Characteristic galls of *H. vaginicola*. Note the rootlike growth at the base of galls. Slightly reduced; D, Galls of *H. captiva* in bluegrass (*Poa pratensis*). There is little external evidence of the galls. Note that the galls are placed end to end. Slightly reduced.



JOINTWORM FLIES OF THE GENUS HARMOLITA.

A, Characteristic galls of *H. hordei*, some clearly showing that the plants were straw-fallen. About actual size; B, Larva of *H. grandis* form *minuta* in a cell in the center of a wheat stem. Greatly enlarged; C, Larva of *H. albomaculata* in a timothy stem (*Phleum pratense*). Greatly enlarged; D, *H. hordei* touching the ovipositor to barley stem, the first process in oviposition; E, forcing the ovipositor into the stem, the second step; F, the ovipositor completely down, the third and last step, and the abdomen resting lightly against the stem. About natural size.

were collected in Ontario, Canada. There are specimens in the Harris collection of the Boston Society of Natural History bearing the label *Isosoma tritici* that were collected in Virginia in 1852. There are also specimens of *tritici* in the same lot. As late as 1892 F. M. Webster (13) stated that—

> He had not reared the depredator, and though in many respects the attack seemed to agree with that of *Isosoma hordei*, as described by Harris and Fitch, yet in many other features it appeared different. In all cases—and he had examined hundreds of wheat straws from northern Ohio—the attack was always above the upper joint. In two cases the upper joint and the one below had been attacked. From many thorough examinations he had found that the stem itself had not been eaten into, the cells being formed in the sheath, but owing to the pressure of the galls on the tender stem the latter had become distorted and the upper portion with the head, where one was produced, was greatly aborted.

This so accurately describes the injury that no doubt is left as to the identity of the insect in question or as to the fact that the species was very widespread and may have been a more serious pest in the early days in Michigan and northern Ohio than *H. tritici*. This is one of the reasons why entomologists had such controversies over *tritici* in the early days. There is not the slightest doubt in the

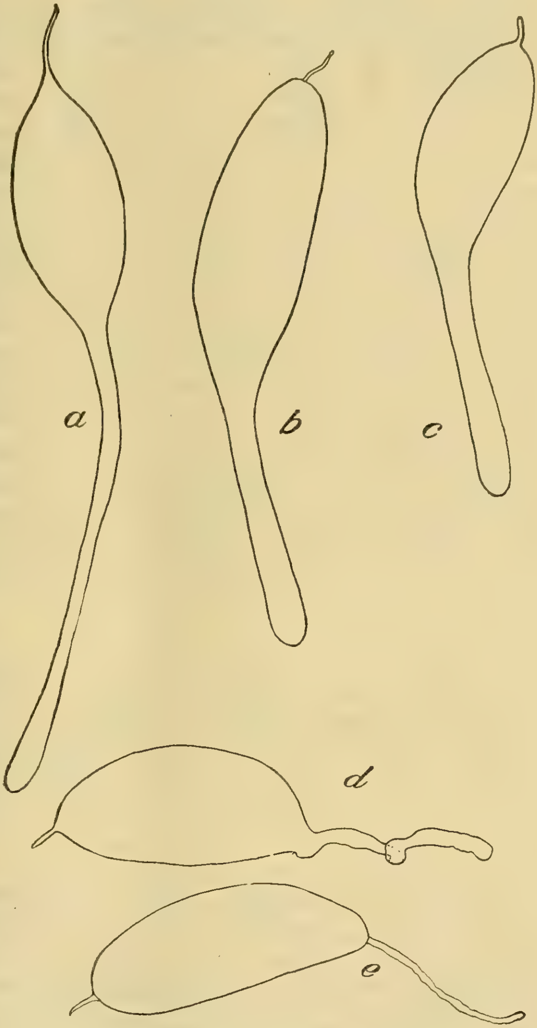


FIG. 7.—Eggs of species of Harmolita: *a*, *H. hesperus*; *b*, *H. websteri*; *c*, *H. albomaculata*; *d*, *H. grandis*, form *grandis*, after oviposition; *e*, *H. grandis*, form *grandis*, just before hatching. All greatly enlarged. (Original.)

writer's mind that if the types of all of the early described species now referred to synonymy were in existence to-day and were recognizable, *vaginicola* would be found among them. *H. vaginicola* was very probably confused with *hordei* and *secalis* as well as *tritici*.

The writer's earliest personal records of *vaginicola* are from collections from eastern Ohio in 1912. Since then he has recorded it from Michigan, New York, and Pennsylvania and has been rearing it in confinement since 1914. Mr. Desla Bennion sent the writer specimens from Salt Lake as early as 1914 and Mr. L. P. Rockwood recently submitted a single gall from Oregon, from which this species has emerged.

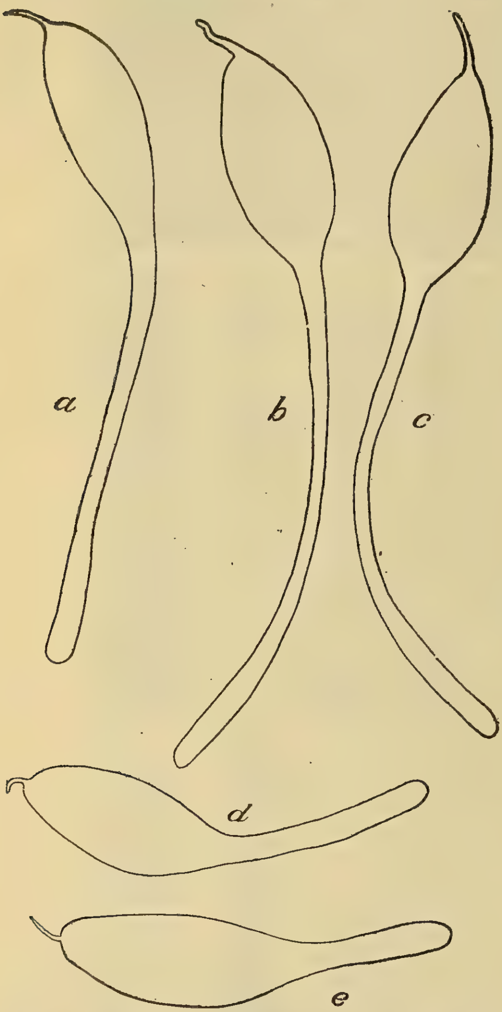


FIG. 8.—Eggs of species of Harmolita: *a*, *H. vaginicola*; *b*, *H. secalis*; *c*, *H. elymicola*; *d*, *H. maculata*; *e*, *H. poae*. All greatly enlarged. (Original.)

MANNER OF INJURY.

H. vaginicola affects the plants in a very peculiar way, and only one other species, namely, *atlantica*, a gall-former in *Agropyron* sp., is known to the writer to affect a plant in a similar manner. The eggs (fig. 8, *a*) are deposited in the tender leaf sheath surrounding the embryonic head. It does not seem possible that the insect can always locate this delicate structure so easily. The result is that as the plant grows, the leaf sheath surrounding the developing head becomes fleshy and thick instead of remaining thin and leaflike. Later this thickened, fleshy leaf becomes hard and woody and compresses the stem to such an extent that little or no sap can reach the developing head. Consequently the head usually protrudes only an inch or two beyond the leaf sheath. Sometimes it does not even burst through the sheath and rarely if ever do any of these heads contain grain (Pl. III, *A*, *B*, *C*). The larval cells are contained in the hardened leaf sheath.

Why this species has not become the dominant pest of wheat, at least among the jointworm group, is inexplicable. It is prolific and the plants attacked seldom if ever produce any grain. The species has been in this country for at least 55 or 60 years. The only explanation that occurs to the writer, of the reason it has not proved more injurious, is that it seems unable to breed in strong, well-grown plants. In other words, by the time the adult emerges in the spring, the majority of the wheat plants are well grown and about to begin heading. This is true, at least, for the States east of the Mississippi River. It seems necessary that plants be small and the heads in an immature tender stage for this species to be able to breed in them. The species absolutely refuses to oviposit in large plants that are about ready to head. Should this pest once become established in the spring wheat belt, the writer is of the opinion that it will be a very serious pest, owing to the fact that the adults would undoubtedly emerge when the wheat plants were young and tender and most attractive to them, as is known to be the case with *grandis* where the spring and winter wheat regions overlap.

HOST PLANTS.

H. vaginicola steadily has refused to breed in any plant other than wheat. The writer never has observed it even to attempt oviposition in any other plant, and, as previously stated, the plants must be young and tender or it will refuse them.

LIFE HISTORY.

There is only one generation a year. The larvæ remain in the wheat stubble until the following spring, then pupate and emerge as adults in May. The abdomen of the female contains 60 to 70 eggs. They are normally thelyotokous. During the 4 years the writer has been rearing this species in confinement no males have been observed, though thousands of specimens have been reared.

THE BARLEY JOINTWORM.[1]

The records show *Harmolita hordei* to be the oldest species recorded in literature in the United States, and, like *tritici*, it has caused a storm of argument. In fact, for many years it was supposed to be the only species present, and even *tritici* was considered a varietal form of it. Harris (7) described this species in 1830. Along in the twenties it caused such serious injury to barley in Massachusetts that the growing of this crop was abandoned in some sections. For years it was a scourge to barley-growing sections in the East. The Eastern States have largely ceased growing barley for a number of years now, and consequently have suffered very little injury. The barley-growing section has moved west, Wisconsin, Minnesota, and the Dakotas now being the most important barley States. Fortunately *hordei* does not seem to have been introduced artificially into those sections, which is the only plausible way it could be transferred from the main barley section in the East. Barley, unlike wheat, is not grown generally in the intervening States, so that there is no chance for *hordei* to spread gradually westward as *tritici* seems to have done.

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[1] *Harmolita hordei* Harris.

During the late summers of 1913 and 1914 the writer visited portions of New York State that were formerly great barley-growing centers. Only a very few infested barley stubbles were found after extended search in 1913, and none were found in 1914. Very little barley is grown there now. The fields, as a rule, are widely separated and the stubble usually is plowed under before *hordei* has had an opportunity to emerge, consequently it has been almost exterminated. This is one of the very rare instances of a once serious pest becoming practically extinct. Its scarcity is such that the writer had never seen a specimen of *hordei* until the spring of 1914, except the few fragmentary specimens in museums.

H. hordei has been confused with *tritici* and *secalis* undoubtedly, and probably with *vaginicola* and others. As the coloration of the legs of *hordei* varies to a considerable degree it is not surprising that confusion arose years ago, since that was one of the main characters used in identifying the species.

MANNER OF INJURY.

Barley plants are affected by *hordei* (Pl. IV, A) in exactly the same manner as wheat plants are by *tritici*. In fact, but for the slightly different appearance of barley straw from wheat straw, the galls could not be separated once they became mixed. When barley plants are badly infested galls may be found above every joint.

HOST PLANTS.

The writer has now been breeding *hordei* in confinement for 4 years and has never succeeded in inducing it to breed in any plant other than barley.

LIFE HISTORY.

This is one of the easiest species to handle in breeding cages. In fact, it breeds more freely than any other species, *tritici* not excepted.

There is only one generation a year, the larvæ remaining in the old barley stubble until the following spring, when they pupate and then emerge as adults during May, at least in the vicinity of Charlottesville, Va. Plate IV, D, E, and F, shows three positions of a female during oviposition. Figure 2, *d*, *e*, shows the egg before and after oviposition.

H. hordei is normally thelyotokous. In a period of 4 years' breeding, during which several thousand specimens have been reared, not more than three or four males have appeared.

Under actual test one female *hordei* deposited 71 eggs in 3 days and then died. Upon dissection 3 eggs were found in her abdomen. From this it would seem that under favorable conditions for egg laying the lives of adult females of the species are very short. If the weather is stormy and cool, however, they will live two or three times as long.

THE RYE JOINTWORM.[1]

The rye jointworm was described in 1861 (4), so it will be seen that it is one of our earliest known species. For years, however, it was considered an invalid species and was thought to be *hordei* masking under a new name. There appears to be no record of the rye jointworm ever doing as serious injury as *tritici*, *hordei*, or *grandis*.

Harmolita secalis, like *hordei*, is almost extinct to-day and apparently for the same reasons. In fact, it never has had the opportunity to become a serious pest on account of the fact that rye probably has never been grown as generally in adjacent fields and through consecutive years as have barley and wheat. The rye jointworm has had to depend largely upon volunteer rye and to make long journeys to the nearest rye fields in order to maintain itself.

The rye jointworm, in common with several other members of the genus, is thelyotokous, males very rarely occurring and apparently being unnecessary to the vital economy of the species. But for the fact that practically every specimen that emerges is a female and capable of perpetuating its kind, *secalis* would undoubtedly have become extinct long ago.

Fitch described *secalis* from Pennsylvania in 1861. F. M. Webster collected the species in Ohio in 1904 and C. N. Ainslie collected it in Michigan in 1906. The writer has collected it in Ohio, Indiana, and Pennsylvania.

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[1] *Harmolita secalis* Fitch.

MANNER OF INJURY.

Rye plants are affected very much in the same way as are wheat by the wheat jointworm and barley by the barley jointworm. The individual cells or galls in rye (Pl. V, A) usually are more clearly defined or outlined than are those of *H. hordei.* Presumably a serious infestation would cause rye to lodge or fall as badly as barley or wheat, since rye is taller and therefore more top-heavy. The writer has never found a serious infestation of *secalis*, apparently because, as previously mentioned, no locality has been found where rye is grown consecutively on contiguous areas, in consequence of which *secalis* is obliged to resort to volunteer plants that spring up in waste places to maintain its existence at all.

HOST PLANTS.

After 3 years of repeated trials this species has refused to breed on any plant other than rye. Like *vaginicola* it prefers young tender plants for oviposition, absolutely refusing to oviposit in large plants or those that have headed.

LIFE HISTORY.

The writer has had this species under observation since 1912, when the first attempts were made to rear it in confinement. It was reared continuously from that time up until 1916. During 4 consecutive years of breeding only 2 or 3 males appeared among hundreds of specimens all of which were the progeny of 6 female and 4 male individuals with which the series was started in 1912.

The larvæ remain in the old stubble throughout the summer, fall, and winter, pupate in the spring, and emerge as adults about the middle of May. The egg is shown in figure 8 at *b*.

The species *secalis* has been confused principally with *hordei* and undoubtedly also with *tritici* and *websteri.*

THE RYE STRAW-WORM.[1]

The rye straw-worm is another early recorded species, having been first described in 1862 by Fitch (5) under the name *Eurytoma hordei.* There is no record that it ever caused serious injury to rye, and under the conditions that prevail to-day of scattered cultivation of this crop there seems little prospect that it will become a serious pest. In fact, like several other species, it seems to be having a very hard fight to maintain its existence. F. M. Webster collected *websteri* in Illinois in 1884, and D. W. Coquillett took it in California in 1885. Webster observed this species in rye stalks in Indiana, Ohio, and Virginia in 1904. Since that time the writer has collected it in Ohio, Indiana, and Pennsylvania.

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[1] *Harmolita websteri* Howard.

MANNER OF INJURY.

The larva works in the center of the stem just at the joint, in the same way as does the summer form of the straw-worm. The writer has never seen a heavy infestation by this species.

HOST PLANTS.

The writer has bred this species for 8 years in confinement and made various attempts to induce it to breed on other hosts, but without success; it confines itself exclusively to rye.

LIFE HISTORY.

Starting originally with 2 females and 1 male, the writer has reared this species in confinement since 1911. All successive generations are the progeny of these individuals, and among several hundred specimens reared only 1 or 2 males have appeared.

There is only one generation a year and the larvæ remain in the old stubble until spring when they change to pupæ, the adults emerging about the middle of May. The egg is shown in figure 7 at *b*.

SPECIES INFESTING THE CULTIVATED GRASSES.

THE TIMOTHY STRAW-WORM.[1]

The timothy straw-worm has been known since 1894, when it was described by Ashmead (1). Nothing seems to have been learned about its life history until recent years. It is very widely distributed and undoubtedly may be found wherever timothy has escaped from cultivation and grows wild. It is not dependent, therefore, upon artificial plantings of timothy.

MANNER OF INJURY.

H. albomaculata occupies the center of the stem, rasping the inner walls and feeding upon the juices of the plant (Pl. IV, C). Usually it is found just at or slightly above the second joint from the root though it may occur at any joint or at every joint. The injury is apparently not sufficient to decrease the hay crop materially, although a heavy infestation certainly would have a considerable effect in lessening the seed crop.

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[1] *Harmolita albomaculata* Ashmead.

HOST PLANTS.

This species has been bred in confinement since 1909 and numerous attempts have been made to rear it on hosts other than timothy, with negative results.

LIFE HISTORY.

Larvæ remain in old stubble and in volunteer growth in waste places throughout the summer and winter, pupating in spring. The adults emerge in May. Males normally occur. The egg is shown in figure 7 at *c*.

THE ORCHARD GRASS STRAW-WORM.[1]

The orchard grass straw-worm was recently described by the writer and Mr. W. T. Emery (10, p. 446). It was found first in 1904 by F. M. Webster, according to Bureau records. Since that time it has been collected by various members of the branch of Cereal and Forage Insect Investigations. The writer has been rearing it in confinement since 1914. It has been reared from orchard grass collected in Massachusetts, New York, Pennsylvania, Ohio, Michigan, Maryland, Virginia, Tennessee, and Utah.

MANNER OF INJURY.

H. dactylicola affects the plant in the same manner as does *albomaculata.* The writer has never found orchard grass as seriously affected as timothy, one reason probably being that it is not grown as generally. Orchard grass probably will not be as seriously injured by *dactylicola* as timothy is by *albomaculata* since the former plant is larger and more woody than timothy.

HOST PLANTS.

This species has not been reared from any host other than orchard grass.

LIFE HISTORY.

Larvæ remain in the old stubble and in old volunteer plants throughout the summer and winter, pupate in the spring, and emerge as adults in May. Males normally occur.

THE BLUE-GRASS JOINTWORM.[2]

Howard (8, p. 13) first described the blue-grass jointworm in 1896 from specimens captured by F. M. Webster in a rye field in 1885 at Normal, Ill. Webster later swept it from timothy and blue-grass at La Fayette, Ind. (14; 8, p. 13). Lintner (9) states that he reared a number of specimens of this jointworm from galls in wheat stems in New York in 1888. It is supposed that *captiva* was the species involved in the latter case, but doubt is cast upon this supposition by Lintner's statement that part of the specimens were typical *hordei* (*tritici*), and part were much larger, the latter being *captiva*. The species the writer knows as *captiva* is much smaller than *tritici*; besides, *captiva* has been reared from galls in blue-grass, and should it breed in wheat also it will be the second species known to infest plants belonging to separate and distinct genera. This is not at all impossible but at present it seems improbable. As the New York case is the only one recorded where the species has been reared from wheat it seems reasonable to suppose that another species than *captiva* was involved.

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[1] *Harmolita dactylicola* Phillips & Emery.

[2] *Harmolita captiva* Howard.

The writer reared specimens of *captiva* from galls in blue-grass collected near Richmond, Ind., in 1905. It has not been reared since. Nothing is known of its life history except that it undoubtedly has only one generation a year and that both males and females were reared. The galls (Pl. III, D) occur near the base of the seed stalk where the stem is thick. As the seed stalks of blue-grass are slender and rather frail the stem at the point where the galls occur does not seem to be very woody. The cells are arranged in a row end to end, there being insufficient room, apparently, for the larvæ to have cells side by side in the stalk as in some other species.

THE BLUE-GRASS STRAW-WORM.[1]

The blue-grass straw-worm was described only recently by the writer and W. T. Emery (10, p. 445) but undoubtedly has been breeding in blue-grass (*Poa pratensis*) for years. Very probably it has been confused with *H. captiva* and perhaps with other species. The first records of *poae* are by F. M. Webster and the writer in 1905. It is a widely distributed species and doubtless can be found wherever blue-grass grows normally.

MANNER OF INJURY.

The writer has never had the opportunity to visit sections that grow blue-grass seed to learn to what extent infestation exists. The only infestation found has been where the grass grows wild in protected places, such as along fences. Pastures usually are kept cropped close by stock and there is little chance for *poae* to breed. It works in the center of the stem and undoubtedly would injure the seed crop greatly, as the seed stalks of blue-grass are slender, soft, and rather fragile, not at all hard and woody like the majority of the grasses affected by other species. The cavity in the stem is scarcely large enough for the larva, and as the walls of the stem are very thin it is easy to see that the larva would consume a large part of the nourishment required for the developing seed and cause serious loss in case of a heavy infestation.

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[1] *Harmolita poae* Phillips and Emery.

HOST PLANTS.

H. poae has not been reared from any host other than blue-grass (*Poa pratensis*) although a number of attempts have been made to breed it in other hosts.

LIFE HISTORY.

As previously indicated, this species hibernates in the seed stalks of blue-grass in waste places and along fences since pastures are kept cropped so closely that there is little chance for it to winter over there. It hibernates as a larva, pupates in spring, and the adult emerges early in May. It is one of the first species to make its appearance in the spring. Males normally occur. The egg is shown in figure 8 at *e*.

THE FESTUCA JOINTWORM.[1]

The Festuca jointworm was described recently by the writer and W. T. Emery (10, p. 454) from specimens reared from material collected by the writer near Youngstown, Ohio, in 1913. Since that date it has been located at other points in Ohio, New Jersey, Pennsylvania, and Virginia. It is the slenderest species among the gall formers, the abdomen being particularly long and narrow.

MANNER OF INJURY.

H. festucae forms galls or hardened enlargements, usually above the second joint from the ground, although they may occur at any joint. The galls (Pl. VI, C) may be prominent or inconspicuous; in the latter case they can be detected only by pinching the stems between the fingers. The injury undoubtedly would be serious to the seed crop and very probably would shorten the hay crop, also, as the flowering stalks are rather slender, and although not quite as frail, they are very much like blue-grass stems in that they are not woody. *Festuca* sp., therefore, would naturally suffer more from attacks of this kind than would orchard grass or timothy.

HOST PLANTS.

The writer has been rearing *festucae* from *Festuca* sp. in confinement and making observations in the field for 5 years and has not reared this species from any other host.

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[1] *Harmolita festucae* Phillips and Emery.

LIFE HISTORY.

As this grass grows naturally in waste places and along fences its jointworm enemy does not depend upon cultivated areas to maintain itself. It winters in the old seed stalks as pupa, the adult emerging near the middle of May. The species is normally thelyotokous, males very rarely occurring.

SPECIES INFESTING WILD GRASSES.

In the preceding pages the writer has given briefly some of the more important facts relating to all the species at present known to infest our grains and cultivated grasses. It may appear at first glance that wheat has rather more than its share of species, especially since it is our most important small grain. On the other hand, the genus Elymus, a wild grass, is the home of nine species, eight of which are gall-formers; *Agropyron* sp., another wild grass, has four species, three of which are gall-formers. The species infesting the wild grasses will be dealt with very briefly. A good many of them may lay a just claim to some consideration from an economic standpoint, from the fact, as previously stated, that they have parasites in common with the more important economic species.

HARMOLITA MACULATA Howard.

Howard (8, p. 15) described this species as *Isosoma maculatum* in 1896 but nothing was known then of its life history. In recent years it has been collected by various members of the branch of Cereal and Forage Insect Investigations. The writer has reared it in confinement since 1912. It has persistently refused to breed in any host other than grasses of the genus Bromus. It does not form galls but lives in the walls of the plant stem, particularly of cheat (*Bromus secalinus*). The cheat stem is almost solid near the base, at least just above the lower joints, the walls being very thick. The egg (fig. 8, *d*) apparently is deposited in the walls of the stem somewhat like the egg of *tritici* and the larva excavates a little tunnel about half an inch long just above the joint (Pl. V, B). There are sometimes two or three to an internode. It is a very widespread species and undoubtedly occurs wherever cheat or other species of Bromus are found.

There is only one generation a year. The species hibernates in the larval stage, pupates in the spring, and the adults emerge in May. It is arrhenotokous under control conditions though in nature both sexes occur.

HARMOLITA ATLANTICA Phillips and Emery.

Harmolita atlantica (10, p. 461) is a species which the writer first reared near Richmond, Ind., in 1909. A few specimens have been taken in Michigan and many in New York. It has been reared sparingly in confinement, not being a very tractable species. It has never been reared from any host other than Agropyron.

This species forms galls in the stems. Some of the galls resemble somewhat those of *tritici*, being placed in the walls of the stem; others resemble those made by *vaginicola*, occurring in the sheath surrounding the head. In the latter case the head does not appear at all. (Pl. VI, B.)

There is only one generation a year, and, as with the majority of species, they pass the winter as larvæ in the galls of the old plant stems, pupate in the spring, and emerge as adults in May. The species is normally thelyotokous, males rarely occurring.

HARMOLITA AGROPYROPHILA Phillips and Emery.

Harmolita agropyrophila (10, p. 450) is the only species, besides *grandis*, that has two generations a year. Singularly enough, Agropyron is one of the few plants infested by Harmolita that produce stems continuously throughout the growing season. The majority of the other jointworm species would find it difficult to maintain two generations a year on a single host unless they were dimorphic like *grandis* and one generation developed in the very young plants.

H. agropyrophila was collected first in 1904 by F. M. Webster. Since that time it has been collected by various members of the branch of Cereal and Forage Insect Investigations. The writer has been rearing and observing this species since 1905, when he first discovered that it has two generations in a year. The larvæ inhabit the center of the stem and may be found at any joint.

The species has never been reared from any host other than Agropyron although repeated attempts have been made to induce it to live on other plants in confinement. There are two generations a year, the first generation emerging very early, during the last week in April and the first week in May. It is one of the first species to emerge. The second generation emerges the latter part of June and the first week in July.[1] The second generation deposits its eggs (fig. 2, *g*) in the young tender stems, and as it is rather late in the season these stems do not produce heads.

HARMOLITA ELYMI French.

This species was described as *Isosoma elymi* in 1882 by G. H. French (6), who reared it from *Elymus americanus* from Carbondale, Ill. The writer's attention was first attracted to it in 1908, when it was learned that it occupied the center of the stem of *Elymus* sp.

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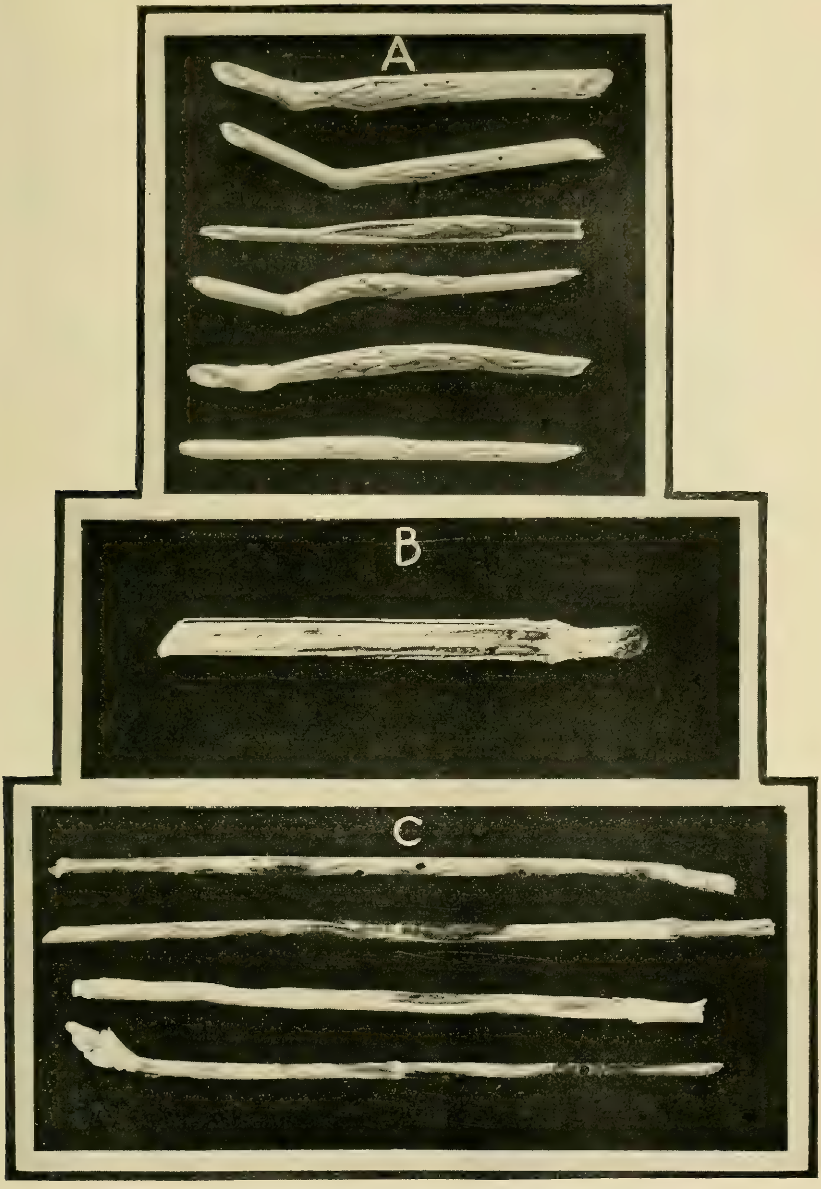
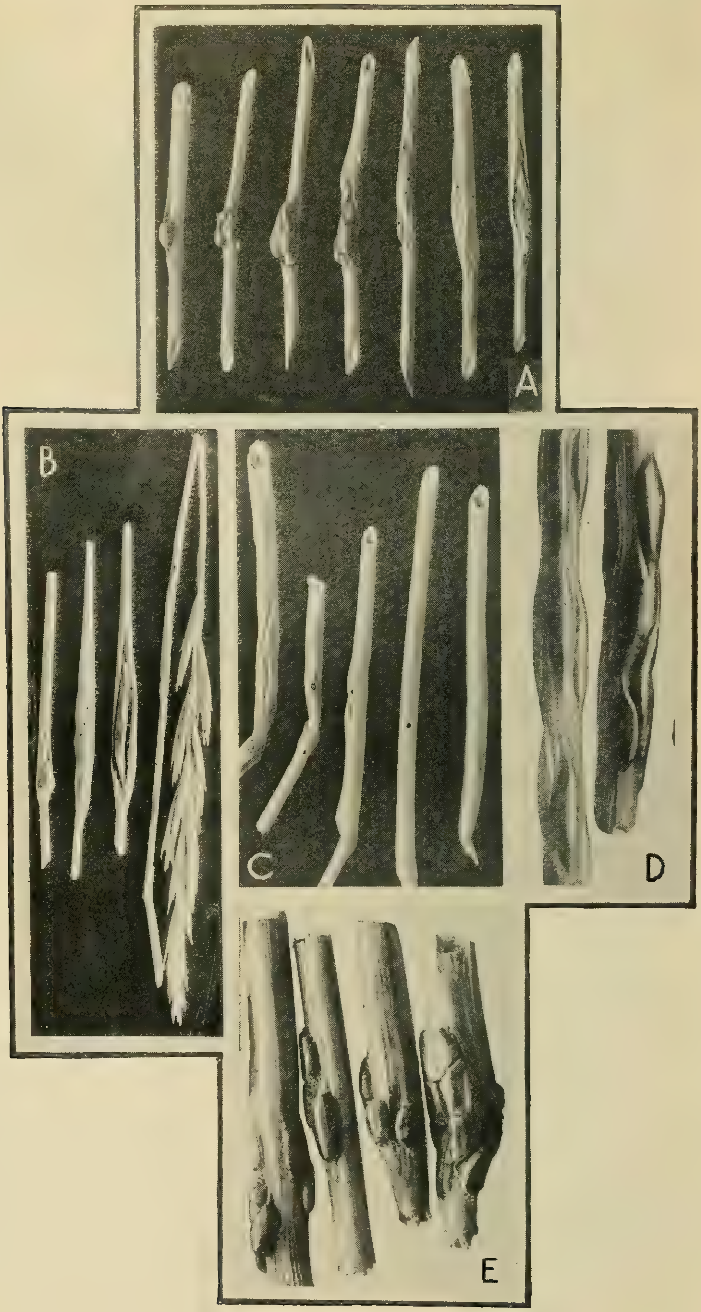
[1] These dates apply to Richmond, Ind.



JOINTWORM FLIES OF THE GENUS HARMOLITA.

A, Characteristic gall of the rye jointworm (*H. secalis*) in rye (about natural size); B, larvæ of *H. maculata* in a cheat stem (about natural size); C, galls of *H. elymivora* in *Elymus* sp. (about natural size).



JOINTWORM FLIES OF THE GENUS HARMOLITA.

A, Characteristic galls of *H. elymicola* in *Elymus* sp., slightly reduced; B, two types of injury to *Agropyron* sp. by *H. atlantica*, those to the left being sheath galls and the long stems to the right being stem galls, slightly reduced; C, Typical galls of the Festuca jointworm (*H. festucae*), about natural size; D, E, characteristic galls of *H. elymophthora*, enlarged slightly. (Photographs D and E by Mr. C. N. Ainslie.)

Nothing was known of its life history until recent years. It has a wide range, being found as far west as Utah, and having been reared from collections of Elymus from Illinois, Indiana, Ohio, and Virginia. It probably occurs wherever *Elymus* sp. grows normally.

H. elymi inhabits the center of the stem of *Elymus* sp. and has never been reared from any other plant, although repeated attempts have been made to rear it from wheat, rye, barley, and some of the grasses. There is only one generation a year. Hibernation is in the larval stage, pupation occurs in the spring, and the adults emerge in May. This species is thelyotokous, males never having been observed.

HARMOLITA ELYMICOLA Phillips and Emery.

Harmolita elymicola (10, p. 460) is the commonest species on Elymus in the Eastern States and is apparently a strictly eastern species, as it has not been collected west of the Mississippi River with the exception of southeastern Missouri. East of the Mississippi it has been taken in Illinois, Indiana, Michigan, Ohio, and Virginia.

It forms very prominent galls or enlargements, usually above the second joint from the base of the plant (Pl. VI, A). It has never been reared from any host other than Elymus. Repeated attempts have been made to breed the species on wheat, barley, and various grasses. It has been observed to oviposit in wheat and barley stems, but nothing ever developed in these stems. Figure 8 *c*, shows eggs of this species.

H. elymicola has only one generation a year. It hibernates as a larva in the old seed stalks, pupates in the spring, and emerges in May. It has proven to be arrhenotokous under control conditions, but both sexes normally occur in nature.

HARMOLITA ELYMIVORA Phillips and Emery.

Harmolita elymivora (10, p. 464) is not nearly as abundant as *elymicola*, though it apparently has a wider range, having been found as far west as Arkansas. It has also been reared from stems of *Elymus* sp. collected in Indiana, Michigan, Ohio, and Virginia.

H. elymivora forms galls in the stems of *Elymus* sp. just below the head. As a result, the head or fruiting body of the plant never develops (Pl. V, C). It is possible that it forms galls of the *elymicola* type also, but the writer has never reared any from such galls.

The life history is similar to that of *elymicola*. Eggs are shown in figure 2, *c*.

HARMOLITA RUFIPES Phillips and Emery.

Harmolita rufipes has been described only recently (10, p. 453), but F. M. Webster is probably the first to have reared it. In Bulletin 42 of the Division of Entomology Prof. Webster confused this species with *H. hordei* Harris, stating that he had reared *hordei* from Elymus at Champaign, Ill. The writer has examined these specimens and they are very clearly *rufipes*. The species resembles *hordei* somewhat in that the legs are reddish brown, but it is much larger than *hordei* and other characters very readily distinguish them. *Rufipes* is apparently a strictly western species, never having been reared any farther east than Champaign, Ill. It has been reared from *Elymus* sp. collected in Kansas, Nebraska, New Mexico, and Utah. It has never been reared from any grass other than *Elymus* sp. Repeated attempts were made by the writer to rear it in confinement at both La Fayette, Ind., and Charlottesville, Va., upon its host, but it has steadily and persistently refused to breed. It apparently would oviposit, but no larvæ ever developed. It forms galls in the stems of *Elymus* sp. Nothing is known of its life history further than that it has a single generation during the year, hibernating in the usual way and emerging in May. Both sexes occur.

HARMOLITA HESPERUS Phillips and Emery.

Harmolita hesperus (10, p. 457) was considered by the writer for quite a while to be *rufipes*. The two species can be distinguished, however, very readily. *H. hesperus* is apparently a strictly western species, having been reared from *Elymus* sp. collected from Kansas and Utah, but it has never been found east of the Mississippi River.

H. hesperus forms galls very much as does *elymicola*. It has not been reared from any plants other than *Hordeum jubatum* and *Elymus* sp. Nothing is known of its life history further than that it hibernates in the usual way and emerges in May. Both sexes occur normally. The writer has never been able to rear this species in confinement, though repeated attempts have been made to rear it in *Elymus* sp., both at La Fayette, Ind., and at Charlottesville, Va. The egg is shown in figure 7 at *a*.

HARMOLITA ELYMOPHTHORA Phillips and Emery.

Harmolita elymophthora (10, p. 465) appears to be a strictly western species also, having been reared only from Nebraska and North Dakota. It was first brought to the writer's attention by C. N. Ainslie, who sent in galls on *Elymus* sp. from which was reared this species. It forms galls in *Elymus* sp. (Pl. VI, D, E), though it is not known whether it has other hosts or not. It has refused to breed in confinement at Charlottesville, Va. It has one generation a year and both males and females normally occur.

HARMOLITA OVATA Phillips and Emery.

Harmolita ovata (10, p. 458) has been reared only from Kansas. It was sent to the writer in the fall of 1914 by E. O. G. Kelly, who was then a member of the Cereal and Forage Insect Investigations force. It forms galls in *Elymus* sp. It is not known whether it has other hosts. It refused to breed in confinement at Charlottesville, Va. There is one generation a year and apparently both males and females occur.

SPECIES WHOSE BIOLOGY IS UNKNOWN.

The species previously treated in this paper have all been reared repeatedly in cages under artificial conditions with the exception of *captiva*, *rufipes*, *hesperus*, *elymophthora*, and *ovata*. The writer has never seen living specimens of the remaining six species described by Phillips and Emery (10)—*poophila*, *agropyrocola*, *occidentalis*, *elymophila*, *elymoxena*, and *gillettei*—or of *bromicola* Howard and *agrostidis* Howard, and practically all that is known concerning them is contained in the meager data incidental to collection. Four of these, *agrostidis*, *bromicola*, *elymoxena*, and *elymophila*, are from California; two, *gillettei* and *poophila*, are from Colorado; one, *agropyrocola*, from Utah; and *occidentalis* from New Mexico. Nothing, of course, is known of their life histories. *Poophila* was reared from *Poa lucida*, sent in by A. D. Hopkins from Husted, Colo.; *agropyrocola* and *occidentalis* were reared from *Agropyron* sp., the former reared from material sent in by Desla Bennion and the latter from material forwarded by V. L. Wildermuth; *bromicola* was reared from *Bromus ciliatus; agrostidis* was reared from *Agrostis* sp.; *elymophila* and *elymoxena* were reared from *Elymus* sp. The four last species were collected by Albert Koebele. *H. gillettei*, as the name implies, was reared by C. P. Gillette and was named for him; the host is unknown. Undoubtedly further observations and collections will add many more new species from the Western States, and more particularly from the Pacific Coast States.

CONTROL MEASURES.

Farmers, as well as entomologists, have concerned themselves very little about controlling these really serious pests. Fortunately or unfortunately, depending upon the point of view, the parasites have taken care of the situation to such an extent that only now and then the jointworm (*H. tritici*) gets out of hand and causes the almost total destruction of a crop in a given locality. Therefore the matter has been viewed very calmly and a toll of from 1 to 5 bushels or more per acre has commonly been tolerated. We have been perfectly content to pay an annual tribute in preference to fighting vigorously to throw off this burden. But for the parasites we should have been obliged to bestir ourselves long ago or else abandon wheat growing in the Eastern States. There is some excuse for this condition of affairs, in that there was no very simple remedy at hand; for example, simply spraying the wheat would not cure the trouble.

The writer has studied the situation for years and has found that most if not all of the so-called remedies are useless. For several winters futile attempts were made to burn over stubble fields in Indiana. In the first place the ground must be frozen or the burning will destroy the young clover and at no time during the winter could the stubble be burned under these conditions. This would be the simplest of all remedies if it were practicable, although it would destroy a source of humus. Another supposed remedy was to plant wheat as far from the old stubble as possible. This is folly unless the farm in question covers an area of several square miles. The jointworm can fly and may be carried by the wind at least for a mile. The suggestion of sowing wheat early, in years of scarcity of the Hessian fly, is equally futile. V. L. Wildermuth, of this bureau, made observations on 51 fields at Groveport, Ohio, in 1909, in order to determine the effect of early and late sowings in relation to jointworm injury. Twenty-eight fields sown from September 10 to 30, with an average date of September 24, showed an average infestation of 38 per cent, with an average yield of 8½ bushels per acre; 15 of these fields produced grain of good, 10 of medium, and 3 of poor quality. On the other hand, 23 fields sown October 1 to 24, with average date of October 10, showed an average infestation of 19 per cent with an average yield of 20 bushels per acre; 11 of these produced grain of good, 9 of medium, and 3 of poor quality. These observations show also that whether the wheat were sown early or late the wheat on poor ground always was infested to a greater degree, provided the fields were equally distant from the source of infestation. The writer's observations confirm this idea.

Some writers have suggested that the larvæ would be destroyed if the infested stubble should pass through stables and then be subjected to the process of decomposition incidental to composted manure. The writer therefore placed infested stubbles in horse stables and allowed them to become mixed with the droppings in the ordinary way. They were then removed to the center of a heap of manure and part of them allowed to remain in the manure all winter while the remainder were removed after having remained in it for two weeks, and then scattered on the ground and allowed to remain there undisturbed throughout the winter and spring. Those remaining in the manure pile were removed the last week in March, and placed in confinement for observation, as were those that were scattered on the ground in early winter. Each lot produced about the same number of adults as did stubble that was allowed to winter in the usual manner in the field. This experiment certainly indicates that there is small hope of destroying the jointworm by passing infested straw through the manure pile.

The writer has been experimenting for the past three years in plowing under wheat stubble for the purpose of observing the effect on infestation the following year in wheat planted on the same ground. This work was done in the vicinity of Charlottesville, Va., where no infestation occurred nearer than 5 or 6 miles. Therefore the data secured should be reliable, as there was no opportunity for the jointworm to come in from neighboring fields. Small plats were used and the infestation was accomplished by bringing in a very large amount of infested stubble from a distance, placing it in the growing wheat, and allowing the adults to emerge and infest the plat. In order to insure heavy infestation, large amounts of badly infested stubble were brought in again from a distance after the wheat was cut, making accurate counts of the number thus brought in, and then carefully estimating the infestation that already existed on the plat. The total number of wheat stems or stubbles was then counted on several representative square yards of the plat. In this way the percentage of artifical infestation could be determined accurately. The infested stubbles which had been introduced, together with the stubbles already standing on the plat, were then turned under. The ground was plowed as soon after harvest as possible, disked, and some crop like peas or soy beans sown. The plat was disked again in the fall at the proper time and reseeded to wheat. In this way an 8 per cent infestation was reduced to 1 per cent the following year. A second trial reduced the infestation from 32 per cent to 3 per cent. A third trial in 1918 reduced a 19 per cent infestation to 2 per cent.

These experiments indicate that plowing under stubble is a very effective remedy. It doubtless would destroy all of the insects if all of the infested stubbles could be completely buried, but it is impossible to do this. Nevertheless it is practicable to control the ravages of the species in this manner. While this method of control would necessitate a change in the existing rotation of crops where wheat is used as a nurse crop for clover, it would seem that it should be adopted if millions of dollars could be saved every year in this manner. Some agronomists admit that it would be practicable to change the existing system of rotation so as to permit plowing down stubble to suppress important insect pests. If this were done not only the jointworm but also the Hessian fly would be controlled, and thus two of the major insect pests of wheat would be largely shorn of their power for harm to our most valuable bread grain.

The barley jointworm, the rye jointworm, and the rye straw-worm undoubtedly can be controlled in the same manner, if the necessity arises.

The wheat straw-worm is very easy to control. Since one generation is wingless it is only necessary to keep down all volunteer wheat and never plant wheat nearer than 40 to 50 yards to infested stubble. This is allowing a wide margin of safety since they are supposed to be able to travel at most only 12 or 15 feet.

Should it become necessary to control the straw-worms and jointworms infesting our cultivated grasses, such as timothy, orchard grass, blue-grass, and *Festuca* sp., this undoubtedly could be accomplished by clipping such fields in the spring in order to delay the appearence of seed stalks until the emergence of the insects, when there would be no place for them to deposit their eggs.

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L. O. HOWARD, Chief

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AMERICAN FOULBROOD

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INTRODUCTION

American foulbrood is an infectious disease of the brood of bees caused by *Bacillus larvae*. The disease is characterized by a decided ropiness of the decaying brood and a peculiar foul odor. It is very widely distributed, is readily recognized, and is of much economic importance. Its existence has been known for a long time, and beekeepers have established many facts concerning it through observations made while practicing their profession. While there is a consensus of opinion among beekeepers on certain points regarding the disorder, there are others on which a diversity of views has existed and still others about which almost nothing of a definite nature has been known.

Former work was directed primarily toward the determination of the cause of the disease. Among the problems considered in the present studies are: The resistance of *Bacillus larvae* to heat, drying, sunlight, fermentation, and disinfectants; the effect of the disease on the colony and on the apiary; and the transmission, diagnosis, and prognosis of the disease. Direct studies on the treatment of the disease have not been attempted by the writer. It will be readily recognized, however, that any treatment that is efficient and at the same time economical must be determined by results obtained by the solution of such problems as those which have received attention in these studies.

The facts may tend to engender fear for the disorder in some instances while in others they may tend to allay it and to offer encouragement. It is hoped, however, that no statement made here will cause any beekeeper to lessen the vigilance that the disease requires, nor, on the other hand, to increase it to a point that would render its control uneconomical.

The discussions in the present paper are based almost entirely upon observations made in the laboratory and in the experimental apiary. The value of the results is emphasized by the fact that the disease produced experimentally and the disease encountered in nature are identical in almost every respect. It is believed that the paper[1] will be of interest not only to the practical beekeeper who wishes to apply the results noted here in the practice of his profession, but also to those who may desire to make further studies on the disease.

NAME OF THE DISEASE

That bees suffer from diseases is recorded in works written before the Christian era but it is not altogether clear what the diseases were. In 1771, Schirach (19)[2] was using the term "foul brood" for an abnormal condition of the brood of the bees, but from his conception of the cause of the disorder one is led to believe that more than one abnormality was being referred to by the term. In 1882 Dzierzon (11) had definitely concluded that there were two kinds of foulbrood. Cheshire expressed a similar belief in August, 1884, but by September he had reached the conclusion that there was but one.

In 1885 Cheshire and Cheyne (9) published an article containing the results of some studies on foulbrood including a description of *Bacillus alvei*. For more than a decade after the appearance of the paper, the view was quite generally accepted that there was but one disease present in the condition that was being called foulbrood and that *B. alvei* was the cause of it. Many American beekeepers, those in New York State especially, became convinced, some time during the decade from 1890 to 1900, that two serious brood diseases were being referred to by the one name—foulbrood.

That there are two such diseases has been conclusively proved. In the United States the one characterized by a decided ropiness of the decaying brood and a peculiar foul odor is now called American foulbrood, and the other one which is not so characterized is called European foulbrood. These two foulbroods are very different, the principal point of similarity being that they are both brood diseases. Both of them occur in Europe as well as in America. Unless these facts are borne in mind the names are likely to be misleading.

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[1] The studies reported in the present paper are similar in nature to those made by the writer on sacbrood (25), Nosema-disease (26), and European foulbrood (27). These papers may be helpful where the discussions in the present one are especially brief. The investigations were completed in September, 1916, and the paper was submitted for publication in October, 1918.

[2] Figures in parenthesis refer to "Literature Cited," p. 42.

The term "foulbrood" (French, *la loque*) in most countries as in America frequently is used in a general sense meaning simply some disorder of bees but no definite disease. In this popular use of the term, either or both of the two foulbroods may be meant. Other brood disorders sometimes are loosely referred to by this general term. "Foulbrood" and "bee pest" or slight modifications of these terms as used in different countries certainly include the disease American foulbrood. In Switzerland no pronounced odor had been observed in connection with American foulbrood and it is referred to as "nichtstinkende Faulbrut" (6, 7, 8); in Austria it is called "Faulbrut" (18); in Germany "Brutpest" (29) and "Faulbrut" (12); in Denmark it is called "Bipest" (2, 3, 4); in England (10) and in Ireland it is called foulbrood or bee pest; and in Australia it is called foulbrood (5).

There are at least three infectious brood diseases of bees but as a rule the one which beekeepers, entomologists, and pathologists have referred to in the past by the term "foulbrood" is the disease American foulbrood, discussed in the present paper.

HEALTHY BROOD AT THE AGE AT WHICH IT DIES OF AMERICAN FOULBROOD

The description of the symptoms of a brood disease as well as the recognition of the disease are very materially aided by making a comparison of diseased with healthy brood. Such a comparison involves the age of the brood, the relative arrangement of the capped and uncapped cells, the appearance of the diseased and of the dead brood, and the relation of the dead larva or pupa to the cell in which it lies. Furthermore, the character of the caps and the odor of the brood-combs should not be overlooked.

In healthy brood-combs a certain regularity is to be expected in the arrangement of areas containing eggs, larvæ, pupæ, and emerging brood, respectively. The cell caps when recently constructed are convex outward (Pl. II, A), but usually become flattened somewhat before the bees are ready to emerge. They are rarely punctured, remaining as a rule entire. In color these combs vary widely from a very light hue when recently constructed to a dark brown when old. Accompanying them is a slight but not disagreeable odor.

In American foulbrood the brood that dies does so nearly always either during the last two days of the four-day prepupal period or the first two days of the pupal period. Such brood, therefore, is in capped cells. A description of a healthy larva at this age is given by the writer in a paper on sacbrood (25) and will be recounted here only briefly.

A larva (prepupa) (Pl. II, D, G; Pl. VI, G), at the age at which death from American foulbrood takes place as a rule, lies extended lengthwise in the cell with its dorsal side against the floor. It is motionless with its head in the direction of the mouth of the cell, its extreme anterior end extending nearly to the cap at the angle formed by the cap and the roof. Its posterior third lies upon the bottom of the cell and extends to the roof; its length is approximately that of the cell, being about one-half of an inch; its width is that of the cavity of the cell, about one-fifth of an inch; and its two lateral sides cover about one-half each of the two lateral walls of the cells. The ventral surface of the larva is in general convex from side to side and concave from end to end. Transverse ridges and furrows give a segmented appearance to the body. An empty space of considerable extent occurs between the ventral surface and the roof of the cell (Pl. VI, G).

The color of the larva at this time is almost white with a slight bluish tint. The entire surface is glistening. The body wall is sufficiently resistant to permit the removal of the larva intact if care is exercised. The tissue mass as seen when the body wall is ruptured is semiliquid and nearly white in appearance. Upon microscopic examination it is found to be made up very largely of fat cells, and to be free from bacteria and other microorganisms.

The change from the larva to the pupa (Pl. VI, B), as far as outward appearances are concerned, takes place rapidly. Infrequently death from the disease takes place during this short period. At this time the bee (Pl. VI, B) has neither the outward form of a larva nor of an adult. This stage of the transformation is recognized by the fact that the head is smaller than that of the complete pupa and the appendages are largely wanting.

The pupa (Pl. IV, A, D) immediately after transformation is similar in form and size to the adult bee. It rests with its back against the floor of the cell and with its antennæ, proboscis, and legs lying along its ventral surface. The posterior third is more pointed and much smaller than the same third of the larva. It lies upon the bottom of the cell but does not extend to the roof.

The color of the pupa at the time of its transformation is nearly white with a slightly bluish tint. The first pigment observed is seen in the compound eyes. Pigmentation of other parts of the body follows. When death from American foulbrood takes place, it does so almost invariably before the time that pigmentation of the body other than of the eyes has occurred. The body wall of the healthy pupa for the first two days of this stage is easily ruptured. Its tissues are soft and when crushed are creamlike in consistency. During this period some care must be exercised in removing the body intact. Soon the body wall toughens so that the form is then maintained rather rigidly.

SYMPTOMS

Much of our knowledge concerning the symptoms of American foulbrood has been gained through observations made by beekeepers while practicing their profession. The apiary in which the disease has been produced by experimental inoculations offers an opportunity to obtain a fairly complete picture of the disease. The present discussion of symptoms of the disorder is based upon observations made on the disease thus produced. During these studies it has been possible to duplicate observations already made by beekeepers on the disease as it occurs in nature and to make still others. It is quite probable that a number of these additional observations could be duplicated on the disease in nature if a sufficiently close study were made.

GENERAL SYMPTOMS

In American foulbrood the symptoms vary within wide limits. The colony may or may not be noticeably weakened. If recently infected the strength will not be affected appreciably, but if the infection has been present for a considerable period the colony will be weakened as a rule. Not infrequently during the course of the disease the strength of the colony is diminished and death is the result. Between these limits any degree of strength may be encountered.

The occasional larva which dies of American foulbrood (Pl. VI, A) before it reaches the age at which healthy larvæ are capped rarely, if ever, is capped after its death. Aside from these few larvæ the brood that dies of American foulbrood does so in capped cells. After death the caps are removed by the adult bee from a large but varying proportion of cells containing dead brood (Pl. III, C, F, I; Pl. V, B), although they are allowed to remain on a considerable proportion of them (Pl. VI, C, E, F; Pl. II, B, C, E, F, H, I; Pl. III, A, B, D, E, G, H; Pl. IV, B, C, E, F; Pl. V, A, C, D, E, F). The irregular condition of the brood comb sometimes referred to by beekeepers as the ''pepperbox'' appearance (Pl. I, A, B, C) is due very largely to the presence of cells containing dead brood which have been uncapped by the bees, occurring among similar cells which have not been uncapped, together with cells containing healthy brood either capped or uncapped.

The caps over dead brood (Pl. II, B) appear in many instances similar to those covering healthy brood. In many instances, however, they are altered, being sometimes punctured (Pl. III, A; Pl. VI, C), sometimes sunken, and sometimes darkened. Sometimes these abnormal appearances are combined. The holes in the caps vary in number and dimensions. Ordinarily there is but one (Pl. III, A), although there may be two (Pl. VI, C) or more. They are usually the size of a pinhead or smaller. The puncturing of the caps is done by the adult bees, and at the time of observation any proportion of the cap may have been removed.

Sunken caps are found only after the disease has been present in the colony for a considerable period, weeks at least. This symptom is most marked after the brood frames have been roughly handled, as in shaking bees from them or shipping them by express or mail (Pl. I, C). This condition of the caps is encountered more frequently in samples shipped to the laboratory than in those taken directly from the affected colony. By rough handling the viscid decaying mass within the cell is brought in contact with the cap, adheres to it and tends to draw the cap inward as it settles, accounting in a large measure for the condition referred to as sunken cappings. The dark caps occur somewhat later and also depend largely upon the presence of decaying brood material within the cell. The caps of many cells containing dead brood, however, are neither sunken nor darkened by its presence.

When recently dead the decaying brood in American foulbrood is light brown in color, the shade deepening as the process of decay continues. The color passes through a chocolate, coffee, and mahogany brown, reaching a very dark shade as it approaches the scale stage.

The body wall of a larva or pupa dead of the disease soon softens and is easily ruptured, making it impossible to remove the remains intact from the cell. As the process of decay continues the mass becomes viscid and before the scale stage is reached the viscidity is such that it is capable of being roped out into fine threads to a distance of 2 or 3 inches and sometimes even more. The scale when dry adheres more or less firmly to the cell wall.

The odor of the brood combs, when it is present, is characteristic of the disease and may be spoken of conveniently as the foulbrood odor. It is never detected in the early stages of the disease and if only scattering cells are present seldom is noticed. When much brood is dying and the disease has been present for weeks, the odor is noticeable and sooner or later becomes marked. When marked it is recognized by its strong and penetrating character and is usually thought of as being disagreeable. The brood combs after their removal from the hive tend to lose this foulbrood odor. The presence and extent of it in samples of the disease vary considerably, the variation depending largely upon the facts just mentioned.

It is possible to recognize most cases of American foulbrood from the general symptoms that are present. On the other hand many cases can be diagnosed only by an exact knowledge of the postmortem conditions of brood dead of the disease. A close study of these appearances, therefore, is advisable. The following somewhat brief description of larvæ and pupæ dead of the disease will suffice in most instances and will serve as a guide to further observations.

SYMPTOMS MANIFESTED BY THE BROOD

Signs that will determine the exact time of death from American foulbrood have not yet been ascertained. As the larvæ and pupæ that die of the disease do so at a period in their growth when healthy brood is motionless, lack of motion is no guide. In the descriptions made in the present paper it is assumed that a larva or pupa is dead if it shows a change from a bluish-white, more or less transparent appearance to one that is more nearly white, more nearly opaque, and shows at the same time a change from the normal turgidity to a slightly flaccid condition.

The appearance of the larval and pupal remains changes gradually from day to day from that of a healthy brood to that of the dried residue—the scale. A description, therefore, that would be correct for one day would be incorrect probably for the following day. Furthermore, all of these remains do not pass through the same changes. For convenience in description, therefore, the various appearances assumed by them are considered in five more or less arbitrary stages. The interpretation of the descriptions will be aided if the description of healthy brood (p. 3) is borne in mind, since the terms used are similar in both instances.

LARVÆ DEAD OF AMERICAN FOULBROOD

The descriptions made of dead larvæ (prepupæ) for the most part will be of those that have died during the 2-day quiescent period just preceding the transformation to the pupa, as most larvæ dying of the disease succumb at this age.

FIRST STAGE

The first symptoms of American foulbrood appear about the end of the first week after infection. From the bluish white of the healthy larva the color changes during this first stage of the disease to a very light brown. The conelike anterior third (Pl. II, E) having settled somewhat, the apex is now slightly farther from the roof. The surface markings in each of the three thirds (Pl. II, H) are very similar to those of a healthy larva. The body wall is easily ruptured, but by care the larva may still be removed intact from the cell. In consistency the decaying tissues are soft and nonviscid.

Sometimes a considerable portion of a larva is removed piecemeal by the bees during the first stage of decay. The remnant (Pl. VI, D), consisting of the posterior third and usually much of the middle third, is found occupying its normal position in the cell. The surface markings are similar to those of the middle and posterior thirds in the first stage of decay. The surface left by the removal of the fragments is somewhat roughened and transverse to the body. These larval remnants are similar to those seen in sacbrood, but in American foulbrood there are fewer of them. When present they form one of the earliest symptoms of the disease.

SECOND STAGE

By the second week after death the larva shows a slightly deeper shade of brown, although still quite light. The anterior third (Pl. II, F) is somewhat darker than the other two thirds. The apex is farther from the roof than in the first stage. The surface markings (Pl. II, I) are now less pronounced throughout. An attempt made at this time to remove the dead larva from the cell results usually in rupturing the body wall. The decaying mass can be entirely removed, however. The consistency of the tissue mass in this stage is somewhat similar to that of moist dough. It has not yet reached the true viscid condition.

THIRD STAGE

By the third week after death the remains have assumed a medium shade of brown, approximating that usually seen in brood cappings. The apex of the anterior third (Pl. III, D) is now widely separated from the roof of the cell, exposing to view the ventral surface of the remains. The transverse ridges and furrows marking the segments (Pl. III, G) are practically obliterated. The edges no longer show the deep notches. The side-to-side convexity is decreased. Evidences of developing head and thoracic appendages are sometimes seen. Transverse tracheæ can usually be observed as white lines across the ventral surface of the abdomen, one in each segment. The body wall is ruptured easily. The decaying mass shows some viscidity and adheres to the walls of the cell.

FOURTH STAGE

By the fourth week after death the color of the dead larva reaches a deep brown, being in shade similar to that of the average older brood combs. The apex of the anterior third (Pl. III, E) is raised only slightly above the upper surface of the decaying larval mass. After being uncapped this third is the first to dry, becoming dark and scale-like. Surface markings practically have disappeared; tracheæ frequently are still visible, especially in the middle third. The ventral surface (Pl. III, H) is now slightly concave from side to side. The posterior third lies upon the bottom of the cell and extends to the roof. The decaying larval mass is now decidedly viscid in consistency. When tested with a toothpick, match, forceps, or any other suitable object it can be drawn out into threadlike strings. This viscid condition of decaying brood is referred to by beekeepers as "ropiness." It is a well known symptom and is much used in the diagnosis of the disease.

FIFTH STAGE

One month or longer after the death of the larva the remains are found to be a thin mass more or less dry and covering most of the floor, some of the side walls, and the bottom of the cell. The dried mass is known to beekeepers as the "scale." Its color is dark brown, similar to that of old brood comb. That portion which was once the anterior third of the larva bears, if at all, only a slight elevation (Pl. III, C, F, I; Pl. VI, E, H). The ventral surface (Pl. III, I) is concave from side to side and quite uniform. The posterior third covers the bottom of the cell and extends to the roof. This can be seen especially well by cutting lengthwise the cell with a scale (Pl. VI, H) in it. It can be seen also that the thickness of a scale throughout the median line is approximately uniform.

As some larvæ die of American foulbrood before the quiescent stage is reached but after being capped, their dead remains may be found occupying not the uniform position just described but various positions in the cell. While the form of the remains, therefore, may vary materially, the color and consistency pass through stages that are similar in all instances.

Occasionally death from American foulbrood takes place while the larva is still younger, i. e., before the time of capping has arrived and while it (Pl. VI, A) is coiled in the cell. This condition is comparatively rare. As the form of the remains depends upon the age of the larva at the time of its death, naturally, the form of the remains of a larva dying before the time for capping will vary materially from the descriptions above. The color and consistency of such a larva during its decay, however, pass through stages that are similar to those already described.

PUPÆ DEAD OF AMERICAN FOULBROOD

Death from American foulbrood does not take place late in the pupal stage but almost always, if not invariably, within the first 2 days after transformation from the larva (prepupa). At this stage the healthy pupæ are practically white, with or without pigment in the compound eyes. Pupæ dead of the disease resemble in color and consistency larvæ dead of the disease. The dead pupæ, as in the case of the larvæ, are described here in five stages.

FIRST STAGE

During the second week following the infection, symptoms of American foulbrood may be seen in pupæ. The cell containing a dead pupa is generally found capped at this time. Upon uncapping, the anterior third (Pl. IV, B) of the pupa will be recognized as resembling very closely that of a healthy one. The surface markings in general (Pl. IV, E) are not particularly unlike those of a healthy pupa. The turgidity is slightly less and the body is to a slight degree more nearly opaque. The body wall is easily ruptured and the tissue mass is soft but not viscid. In general the consistency is similar to that of a larva in the first stage of decay.

SECOND STAGE

The process of decay continuing, the tissues soften and the pupal mass settles, distorting its form. The anterior third (Pl. IV, C) has settled to the floor of the cell and is separated from the roof by a considerable distance. The face is directed more nearly upward. The surface markings (Pl. IV, F) of each third are less distinct. The legs and other appendages rest upon the body. The body wall is at this time very easily ruptured and the tissues are soft. The color and consistency are similar to those of the second stage of decay of the larva.

THIRD STAGE

During the third stage the appendages are less easily distinguished; as they settle they merge more or less with the decaying mass of the head, thorax, and abdomen. One exception should be mentioned. Some of the mouthparts (Pl. V, A), chiefly the proboscis, adhere to the roof of the cell. This condition has often been noted by the beekeepers. The face of the pupa in this stage is directed still more nearly upward than in the preceding stage. The head is not infrequently found to be disfigured through drying or being gnawed or both. The ventral surface of the middle third (Pl. V, D) is still, in general, convex from side to side. The color and consistency are similar to those of the same stage in the larvæ. When the pupal mass is removed white lines may be seen in it. These are tracheæ.

FOURTH STAGE

In the fourth stage evidence of drying is marked and pupal remains are changed still further. The anterior third (Pl. V, B) bears only a slight resemblance to that of the pupa. Through settling of the mass and through drying it is now very much flattened. The ventral surface of the middle and posterior thirds (Pl. V, E) are still slightly convex from side to side and are roughened, due chiefly to the remains of the legs and other appendages. The color of the decaying mass in the fourth stage is a dark brown similar to that of old brood comb. This mahogany-hued mass is viscid in consistency, showing the ropiness that characterizes brood dead of American foulbrood.

FIFTH STAGE

Finally after a few weeks of decay and drying there is to be found in the cell the more or less dry residue of the dead pupa—the scale (Pl. V, C, F; Pl. VI, F, I). It covers most of the floor and some of the side walls and only a portion of the bottom. The pupal scale is in many respects similar to the larval scale. It is concave from side to side. The ventral surface is slightly roughened by the dry decayed appendages. The posterior third extends only slightly upon the bottom of the cell. This can be demonstrated by cutting the scale (Pl. VI, I) lengthwise as it occupies its position in the cell. The scale is dark brown resembling in shade that of old brood comb. It adheres rather firmly to the cell but with care can be removed from it. When thoroughly dry and removed it is found to be quite brittle.

ETIOLOGY

PREDISPOSING CAUSES

Age.—American foulbrood infection takes place only during the feeding stage of larvæ. Death occurs almost invariably after the feeding stage is passed, i. e., after capping, and either while in the larval stage or soon after transformation to the pupa. Older pupæ do not die as a result of the disease and adult bees do not become infected.

Sex.—That worker, drone, and queen larvæ are all susceptible to the disease has been demonstrated during these studies. Affected drone brood is encountered less often in the diagnosis of this disease than in that of European foulbrood. The writer has encountered queen larvæ affected by American foulbrood in experimental colonies only, although very probably diseased queen larvæ do occur in nature also.

Race.—Thus far no race of bees has been shown to possess complete immunity from the disease. In the experimental inoculations recorded in the present paper bees mixed with Italian blood were used for the most part. The queens in many of the colonies were purchased as "untested Italians." At least five colonies of "tested Italians," two of "tested Carniolans," and two "tested Caucasians" were inoculated. Among the colonies used there were also several common black bees. The disease was readily produced in all of these strains. Furthermore, the results obtained from the examination of numerous samples of diseased brood received from beekeepers throughout the United States indicate that all strains of bees commonly found in American apiaries are susceptible to infection with American foulbrood. No definite conclusion can be drawn at the present time regarding the relative immunity possessed by the different races.

Climate.—It is quite well known that American foulbrood is very widely distributed. The writer has examined samples of the disease from England, France, Germany, Switzerland, New Zealand, Canada, Cuba, and various parts of the United States. This is sufficient to show that the disease exists under a great variety of climatic conditions. The practical import of the observation is that the presence of American foulbrood in any particular locality can not be attributed entirely to the climatic conditions of the region.

Season.—In general the losses from American foulbrood occur later in the bee season than do losses from either sacbrood or European foulbrood. Experimental inoculations have shown that the larvæ of bees are susceptible at all seasons and that the disease can be produced whenever brood is being reared. It would seem, therefore, that the severity of the disease is due more to environmental conditions existing at the different seasons than to any difference in the susceptibility of the larvæ during these periods.

Food.—Since American foulbrood occurs in such widely different localities (see "*Climate*"), wherein the food of bees varies almost as much as it is possible for it to vary, it may be concluded that the quality of the food used by bees has very little, if anything, to do in the causation of the disease. Furthermore, it is found experimentally that the disease can be produced when the colony is well supplied with food, when there is a moderate quantity present, or when there is a scarcity. It would seem from the facts at hand that the course of the disease probably is governed to some extent indirectly by the quantity of food present and to a less degree, if at all, by its quality. The value of these factors has not been determined but it is certainly not great in either case.

EXCITING CAUSE

During the period from 1885 to 1902 (p. 2), *Bacillus alvei* was assumed quite generally to be the exciting cause of foulbrood. From 1902 to 1907 much interest was manifested in the problem relating to the cause of the foulbroods. This is shown by the investigations of Lambotte (13) in Belgium, Burri (6, 7) in Switzerland, Bahr (2) in Denmark, Maassen (14) and Erne (12) in Germany, and those of the writer.

The writer's experience with the bee diseases began in 1902 when he was working under the direction of Dr. V. A. Moore. In the first studies made, spores were found in very large numbers in the scales of the ropy foulbrood. As these did not grow on the media commonly used in a laboratory (17) it was at once recognized that they were not the spores of *Bacillus alvei.* Furthermore, as *B. alvei* was not found in any of the samples of the ropy disease, the conclusion was drawn very naturally that this bacillus could not possibly be its cause.

Bacillus alvei was found to be present, however, with much regularity and in great numbers in the brood disease that is not characterized by ropiness and foul odor—European foulbrood. These observations taught, therefore, that *B. alvei* was not to be associated with American foulbrood—the ropy, foul-smelling disease—but with European foulbrood, which does not possess these characteristics.

After beekeepers had convinced themselves that there were two foulbroods, one with a peculiar foul odor and showing a marked ropiness of the dead brood and the other without these characters, *B. alvei* unfortunately remained in the literature as the cause of the ropy, foul-smelling disease. This fact accounts for not a little of the confusion that has existed in connection with the brood diseases. It should be remembered that *B. alvei* is not the exciting cause of any bee disease.

The writer found (20) that the spores which had refused to germinate on the media ordinarily used in the laboratory would germinate and the bacillus would grow in an agar medium in the preparation of which bee larvæ were used. Satisfactory cultures for experimental purposes were not obtained with this medium, however. Later he (23) succeeded in devising a medium (p. 18) by the use of which pure cultures of *Bacillus larvae* suitable for experimental work could be obtained in abundance and with such cultures American foulbrood was produced by inoculation, the experimentally produced disease manifesting symptoms that are typical of American foulbrood encountered in nature.

BACILLUS LARVAE

Bacillus larvae, the cause of American foulbrood, had been seen by microscopists doubtless long before it was cultivated successfully in the laboratory. The species requires special media for its cultivation. Success in the germination of its spores was attained in 1903 on an agar made from bee larvæ. Pending more definite information regarding the bacillus the writer (20) referred to it by the term, Bacillus "X." Further knowledge concerning the species was gained during the summer of 1904, and it was given the name *Bacillus larvae* (White 21, 22). Burri (6) in Switzerland, working on the disease entirely independently, also recognized the fact that the spores present in such large numbers in the scales represented a new species that was difficult of cultivation. Maassen (14) has referred to the species as *Bacillus brandenburgiensis*, and Cowan (10) has referred to it as *Bacillus burrii* (8).

Occurrence.—Bacillus larvae occurs in the brood of bees dead of American foulbrood and where contaminations with such material have taken place.

Morphology.—The vegetative form is a slender rod with ends slightly rounded and with a tendency to grow in chains (fig. 1; Pl. VII, A). It varies markedly in length, depending largely upon the medium used in its cultivation. On the surface of brood-filtrate agar it is more often from 2.5 to 5 μ in length and about 0.5 μ in breadth. In a liquid medium it is usually much longer, becoming then frequently filamentous in character. During the vegetative stage the bacillus undergoes changes (fig. 5; Pl. VII, E, F, G, H) seldom noted for the bacteria. The rod possesses numerous flagella which are peritrichic in arrangement (fig. 2; Pl. VII, C).

Giant whips.—Giant whips occur (fig. 6; Pl. VII, F, G, H) in large numbers, being found especially numerous in the water of condensation of brood-filtrate agar cultures. These corkscrewlike structures vary widely in their dimensions from scarcely visible coiled filaments to bodies several micra in diameter.

Motility.—The bacillus is moderately motile in young cultures taken from the surface of brood-filtrate agar but is somewhat more sluggish when grown in liquid cultures.

Spore formation.—On brood-filtrate agar evidence of spore formation is present about the third day. The rod is swollen near the center where the spore is formed, being then spindle-shaped (fig. 3; Pl. VII, B). In a few days numerous spores free from the rods are to be seen (fig. 4; Pl. VII, D). They measure about 0.6 by 1.3 μ. In some environments few or no spores are produced. This occurs in liquid media, deep in solid media, and on media containing glycerin, mannite, or glucose. Some of the other sugars and also honey inhibit spore formation.

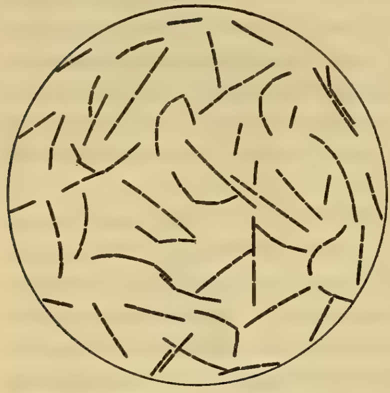

FIG. 1.—*Bacillus larvae:* Vegetative form.

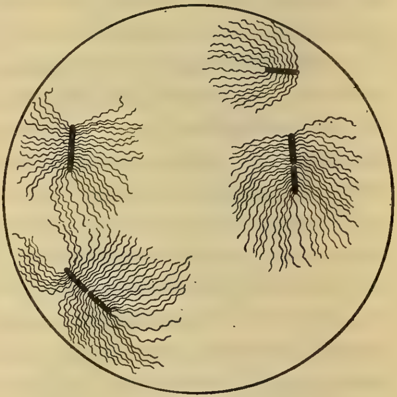

FIG. 2.—*Bacillus larvae:* The flagella.

Staining properties.—The rods color readily and uniformly with the analine stains, and are Gram-positive. The spores are quite resistant to stains.

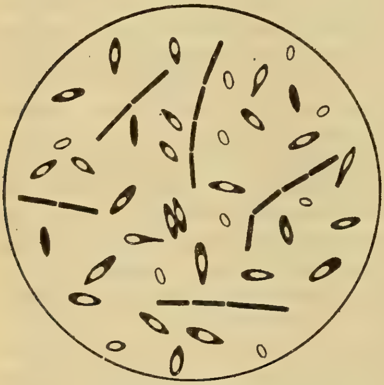

FIG. 3.—*Bacillus larvae:* Spore formation.

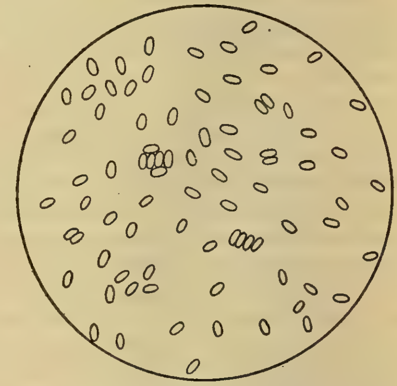

FIG. 4.—*Bacillus larvae:* The spores.

Oxygen requirements.—When bee larvæ agar alone is employed and inoculations are made with spores following Liborius' method for anaerobes, growth as a rule has appeared more often near to than on the surface (Pl. VIII, E, F, G, H, I). Subcultures on brood-filtrate agar (Pl. VIII, D) and egg-yolk-suspension agar or their combination yield abundant surface growth.

Agar slant.—On the surface of inclined brood-filtrate agar subcultures (Pl. VIII, D) grow rapidly, producing a moderate to heavy growth in 24 hours. This growth tends to spread somewhat from the area inoculated, is grayish-white, and slightly viscid. It presents a more or less uniform border, a smooth surface, and a ground-glass appearance. Older cultures are less prominent than the younger ones.

Agar plates.—Colonies on the surface of agar vary in size depending upon the number present. When only a few are present not infrequently they spread and attain a diameter of a centimeter or more. The border is clearly defined and uniform. The growth is only slightly raised and has a smooth surface and a ground-glass appearance (Pl. VIII, A, B). Deep colonies vary from lenticular to irregular in form with filamentous outgrowths from portions of their surface (Pl. VIII, A, C).

Fermentation.—Carbohydrate liquid media as ordinarily prepared are not suitable for the growth of *Bacillus larvae.* In some of these after a considerable period a slight growth may appear at the bottom of the tubes. A little brood-filtrate or egg-suspension added to the media improves it. No visible gas is formed but in some instances slight acidity is produced.

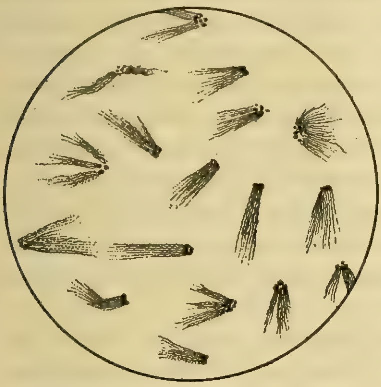

Fig. 5.—*Bacillus larvae*, illustrating an interesting feature of the organism.

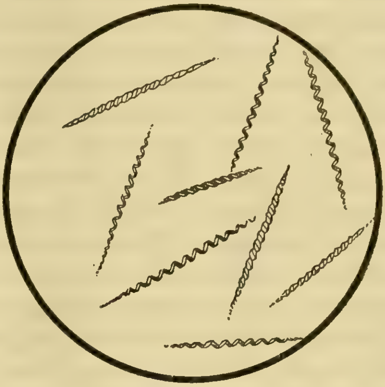

Fig. 6.—Giant whips from cultures of *Bacillus larvae.*

Gelatin.—No growth takes place in plain or in brood-filtrate gelatin at temperatures at which it remains congealed.

Power to resist disinfectants.—The spores of *Bacillus larvae* are very resistant to heat. When suspended in water the more resistant ones require as much as 100° C. maintained for 11 minutes to destroy them and when suspended in honey require a half hour or more (p. 22). They resist respectively 5 per cent carbolic acid for months; 1 to 1,000 mercuric chlorid for days; 10 per cent formalin for hours; and 20 per cent formalin for minutes; each acting at room temperature.

Pathogenesis.—*Bacillus larvae* is pathogenic for the brood of honeybees. Infection takes place during the feeding period of the larvæ by way of the alimentary tract. The brood dies of the disease in the larval, prepupal or early pupal stages. The earliest symptoms to be observed following inoculation usually occur in prepupæ during the seventh day after the feeding, rarely earlier. The earliest evidence of infection in pupæ occurs one or two days later. The bacilli are at this time distributed throughout the body. Adult bees, rabbits, guinea pigs, and rats are not susceptible to infection with the parasite.

While the dead brood in the scale stage and in other later stages of decay in American foulbrood invariably contains spores of *Bacillus larvae* in immense numbers, a microscopic examination of earlier stages shows not only few spores but also a comparatively small number of rods. A partial explanation at least of this rather unexpected fact was gathered from the study of the organism on artificial media. Here it was found that the rods at times undergo interesting but as yet undetermined changes. On glucose and other media, when the growth is luxuriant and the spore formation is very much inhibited, it is noted that in older cultures rods are comparatively few in number but in their stead are forms which are neither rods nor spores but are small, more or less spherical bodies (Pl. VII, F, G, H). The exact transformation that has taken place in the bacillus to produce these bodies is not known. Something of the phenomenon has been learned through a study of the rods stained with a flagellar stain employing in the method a light aqueous suspension of a young culture. In such preparations there is seen within the rods a number of individual elements, apparently, each of which is supplied with flagella. These structures become independent and separate from the rod proper (fig. 5; Pl. VII, E, F, G, H). In the cultures are found also, especially in the condensation water of brood-filtrate-agar slant cultures (Pl. VIII, D), giant whips (fig. 6; Pl. VII, F, G, H) of various sizes. That the little-understood changes that take place in the vegetative forms bear a close relation to the formation of the giant whips can readily be suspected.

Definite data have been sought to prove the identity of the ropy foulbrood of the different countries. Samples of brood comb containing disease material were received from Canada, Cuba, England, France, Germany, New Zealand, and Switzerland. The findings from studies made on these were compared each with the other and with the findings from many samples from the United States. Spores of *Bacillus larvae* in very large numbers and practically in pure cultures were present in every one. In each instance one of the special media (p. 18, 19) required for the cultivation of this species was needed. Culturally the bacillus was the same from all of the samples. The disease produced by the inoculation of colonies of bees was also similar in every instance. Sera from rabbits immunized with cultures from American sources agglutinated in high dilutions cultures from English, New Zealand, and Switzerland sources at least, these being all that were tested in this way. The evidence, therefore, justifies the conclusion that the ropy foulbrood of each of the different countries mentioned above is identically the same disease.

Four rabbits inoculated with pure cultures of *Bacillus larvae* showed comparatively little reaction. In each instance there was used a moderately clouded suspension in normal salt solution made from the surface of the brood-filtrate-agar slant culture about 24 hours old. Two of them were inoculated subcutaneously with 1 and 2 c. c. of the suspension, respectively; one received the culture intraperitoneally and one intravenously. The temperature taken of the latter two throughout the day of the inoculation was found to be increased about 3° F. following the inoculation. The next day they were somewhat sluggish with impaired appetite. The temperature, however, soon declined to normal and their feeding became normal. The 1,500 gram rabbits were from 100 to 200 grams light in weight on the day after the inoculation but soon the loss was regained. Observations were made over a period of 2 months. Autopsies on the chloroformed animals showed no abnormalities worthy of note.

Four guinea pigs inoculated subcutaneously with cultures similar to those used in the rabbit inoculations showed only slight reaction. The temperature of the one taken throughout the day of inoculation showed a rise of about 2° F. but was normal thereafter. No loss in the weight of these 400 to 500 gram guinea pigs was appreciable. One died in 10 days, apparently from causes foreign to the inoculation. The remaining three were chloroformed after 6 weeks and presented no abnormalities of note at autopsy.

Two gray rats were inoculated subcutaneously, one with the vegetative and the other with the spore form of *Bacillus larvae*. These proved to be refractory. After 4 weeks they were chloroformed and at autopsy no abnormality of interest was noted except a slight infiltration at the point of inoculation in the animal receiving the vegetative culture, and a small abscess in the case of the animal receiving the spore suspension. In the abscess spores were present.

TECHNIQUE

Much of the time devoted to the study of American foulbrood has been consumed in the study of technique. Special media were required and the method of conducting the experimental studies had to be developed.

MEDIA

Failure to recognize the fact that the spores occurring in such large numbers in the brood dead of American foulbrood do not grow on the media ordinarily used in the laboratory has caused a number of workers to go astray and has contributed not a little to the confusion that has existed concerning the brood diseases. Lambotte (13) in Belgium experienced some difficulty in obtaining cultures following inoculations with the spore-bearing disease material. He made a medium using the brood of bees in its preparation and with it obtained a growth which he interpreted as being the species represented by the numerous spores present in the brood dead of the disease. The interpretation was evidently incorrect. The culture which he obtained he identified as a member of the *mesentericus* group. In 1903, before learning of Lambotte's work, the writer (20) had made an agar using bee larvæ and obtained a germination of the spores of the ropy foulbrood. In this bee-larvæ agar[1] the growth is always slow and somewhat feeble. Spores are produced to a slight extent only or not at all. Such cultures are unsuitable for experimental purposes.

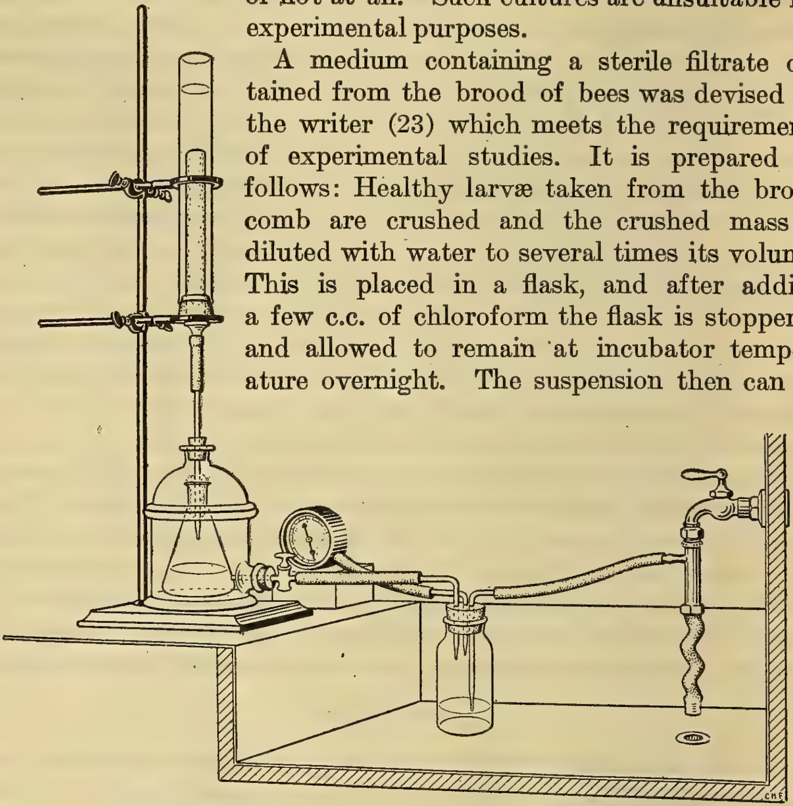

FIG. 7.—A convenient method for obtaining sterile filtrates.

A medium containing a sterile filtrate obtained from the brood of bees was devised by the writer (23) which meets the requirements of experimental studies. It is prepared as follows: Healthy larvæ taken from the brood comb are crushed and the crushed mass is diluted with water to several times its volume. This is placed in a flask, and after adding a few c.c. of chloroform the flask is stoppered and allowed to remain at incubator temperature overnight. The suspension then can be filtered easily by using any bacteria-proof filter[2] (fig. 7). The filtrate is pipetted aseptically into sterile tubes and stored until needed. About 1 c.c. of the brood filtrate is added to each 5 c.c. of agar liquefied and cooled to about 50° C. After being inclined the medium is ready for use and may be stored. Plating for pure cultures may be done by adding the brood filtrate to the agar at the time the plates are made.[1]

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[1] Larvæ, prepupæ, or pupæ recently transformed furnish satisfactory brood material for making the bee-larvæ media. These are picked from the brood combs, crushed, and used as meat in formulas ordinarily followed in making bouillon and agar. Excess heating should be avoided. In making the inoculations an aqueous suspension of the spore-containing material heated to 100° C. for one or two minutes should be used. A tube of the special agar liquefied is inoculated with a loopful of the heated suspension. After cooling it is incubated at about 38° C. Three days or more may be required to produce a visible growth (Pl. VIII, E, F, G, H, I).

[2] In caring for and using the filter cylinders in these studies the following course has been pursued: The cylinder is immersed in water for a few hours or over night and is then sterilized in the autoclave. After being used for filtering a brood suspension it is washed in water without scrubbing. To remove further the brood material water is drawn through the cylinder under pressure as in filtering. As a rule it is again immersed in water and allowed to remain over night, after which, the filter being assembled, water is filtered again. It is then ready for use and may be stored until needed. Cylinders which have been used repeatedly in this way have lost none of their efficiency. The vacuum chamber is made in two sections similar to a Novy jar. Vaseline is used on the wide ground flanges. No rubber band or clamps are needed.

The flasks used in the vacuum chamber of the apparatus before being sterilized are stoppered with cotton wrapped about a small-sized test tube. The cylinder having been immersed in water is sterilized together with the rubber connections and glass tubing in place, but without the glass mantle. In assembling the apparatus sterilized connection between the cylinder and flask in the vacuum chamber is readily obtained through the opening in the plug left by removing the test tube. After a vacuum has been established in the chamber the stopcock may be closed and the pump turned off.

When it is desired to obtain cultures from the spore form of *Bacillus larvae*, brood-filtrate agar is not a suitable medium in itself. The spores should be germinated first by inoculating bee-larvæ agar (p. 18) or egg-yolk-suspension agar. By plating in 2 or 3 days the vegetative form thus obtained, using brood-filtrate agar, pure cultures can be assured. Studies have shown, however, that *Bacillus larvae* is present in practically pure cultures in brood dead of the disease, and by heating the spore-containing material in aqueous suspension at 100° C. for one or two minutes as suggested above the occasional contaminating organisms are eliminated usually without plating.

Bee-larvæ agar is limited in its usefulness on account of the large amount of brood required in its preparation. A more suitable medium, therefore, was sought. An unheated egg-yolk agar was found by the writer (28) to be very satisfactory. This is prepared as follows: Fresh eggs are used. After having been immersed in a disinfecting solution the shell is broken, the white of the egg is poured off, and the yolk is dropped into a flask containing about 70 c.c. of sterile water. With a sterile pipette the aqueous suspension of yolk, resulting from agitating the flask, is transferred to sterile tubes and stored until needed. In making an egg-yolk-suspension agar about 1 c.c. of the egg-yolk suspension is added to each 5 c.c. of agar in tubes liquefied and cooled to about 50° C. The agar is inclined and may be stored until needed.[2]

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[1] Larvæ, prepupæ, or young pupæ may be used in obtaining the brood filtrate. The use of sterile water is a good precaution in making the dilution of the crushed brood mass. A dilution of 1 to 10 up to 1 to 50 gives very satisfactory results, although lower and higher dilutions have been used with success, while at incubator temperature an autodigestion apparently takes place. The "autodigested" suspension is passed through filter paper before the bacteria-proof filter is used. For the latter the Pasteur-Chamberland F is very satisfactory. (Fig. 7.) The B grade has been used but the filtering is slower. The Berkefeld N has also been employed, but is less efficient. In using this latter type of filter gravity alone should be employed. If the weather is warm, or if the filtering is not to be done for a few days, the aqueous suspension may be allowed to remain at room temperature. This permits the changes which take place to advance sufficiently to make the filtering process comparatively easy. The chloroform saturated suspension of brood material has been kept at room temperature for more than three years without its usefulness being impaired to any appreciable extent. After a considerable period the suspension becomes practically sterile and has been used without being filtered. When an early use of the filtrate is desired its sterility should be tested by placing the tubes containing it at incubator temperature for a few days. Sometimes it is desirable to use other brood-filtrate media than the agar. In this event a small amount of brood-filtrate may be added to any one of the media ordinarily used in the laboratory. Such special media usually support a growth of *Bacillus larvae* when inoculated with the vegetative form of the organism.

[2] Eggs obtained from the market labeled "strictly fresh" have been suitable as a rule for the egg-yolk suspension. Eggs known to have been recently produced are to be preferred, however. Almost any of the more common efficient disinfecting solutions may be employed for sterilizing the eggshell. Aqueous solution of mercuric chlorid 1:1000; carbolic acid 5 per cent; formalin 10 per cent; and alcohol each have been used, mercuric chlorid being preferred. To insure sterility autoclaving of the flasks with the contained water has been practiced. A wide-mouthed flask is preferred. In securing the yolk aseptically, it

EXPERIMENTAL INOCULATIONS

A very satisfactory colony for inoculation purposes is a queen-right nucleus that can be accommodated comfortably on from 3 to 5 brood frames approximating the Langstroth size. The hive, the arrangement of the apiary, the colony, the feeding, and the manipulations in general are similar in the experimental study of American foulbrood to those employed by the writer in the study of sacbrood (25), Nosema-disease (26), and European foulbrood (27). The inoculated colonies were, therefore, in the open. Precautions tending to minimize the likelihood of robbing, swarming, absconding, and the accidental straying or drifting of bees should not be overlooked.

The inoculations are made by feeding a suspension of the spores of *Bacillus larvae* in sirup or honey, the spores being obtained from pure cultures or from brood dead of American foulbrood. Three or four tubes of spore-containing cultures grown on brood-filtrate or egg-yolk-suspension agar furnish a suitable quantity of the virus. Likewise the spores contained in three or four scales give satisfactory results. In some experiments, feedings made on successive days are desirable. Direct inoculation by means of a capillary pipette is less satisfactory in experiments on American foulbrood than in those on sacbrood.[1]

The first symptoms of American foulbrood to be observed following the inoculation usually appear in the worker larvæ by the end of the first week and not earlier than the sixth day. The affected larvæ are in capped cells. Not infrequently the first evidence of disease noticed is the remains in cells here and there of partially removed

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is convenient to break the sterilized shell about one end of the egg, remove the pieces with flamed forceps, and, after making a small hole in the other end, pour off the white. The yolk remaining is poured into the flask. By breaking the limiting membrane of the yolk at the time of pouring into the flask the process is facilitated. Different degrees of dilution of the egg yolk have been employed, 60 c.c. to 80 c.c. of water giving satisfactory results. Any ingredient, such as the sugars, desired in the final medium may be added to the water of the flasks. The egg of the hen has been used in most of the studies reported here. Eggs of the duck were also found to be suitable. Occasionally a contamination of the egg suspension will be found. In these cases the suspension becomes firm after incubation resembling then the consistency of coagulated milk cultures. If the contamination is present it will be apparent in a few days after storing, or it may be determined earlier at incubator temperature. The sterile egg-yolk suspension as an ingredient for special media retains its efficiency for a long period. Indeed an aqueous suspension of the dry residue from the yolk supension was found to be efficient after 3 years, although its value is then apparently somewhat impaired.

Maassen (15) used bee-larvæ and also brain agar in studying *Bacillus larvae*. The egg-yolk suspension agar, in the writer's experience, has advantages over the brain agar.

[1] Cultures on the surface of agar are readily suspended in water as is also the disease material in the decaying larvæ and scales of American foulbrood. These aqueous suspensions are used in making the sirup or honey suspensions. From 1 to 3 c.c. of water for each scale is a convenient proportion. Sirup is made by bringing to the boiling point an aqueous suspension of granulated sugar in which the sugar used exceeds that of the water. When honey is used for the spore suspension it is diluted with water, the amount of water added being slightly less than that of honey. In most instances honey is less suitable than sirup inasmuch as it tends to encourage robbing especially during a dearth of nectar, it needs to be sterilized before use, and is more expensive. It was found that less than one scale is sufficient disease material to produce a considerable amount of disease in the colony. In some experiments one scale, therefore, might supply all of the spores needed although the use of a somewhat greater quantity of material is advisable in most instances.

larvæ (Pl. VI, D), about one-third of the larva being removed. The transparency seen in healthy larvæ disappears, and the bodies of the ones affected become more nearly opaque. Soon the color assumes a tint of brown which deepens as the process of decay continues, passing through chocolate, coffee, and mahogany shades. In the earliest stages of the disease the body wall is ruptured more easily and the tissues are softer than in healthy brood. As the disease advances a ropiness of the decaying brood is to be observed, the characteristic odor appears, and a loss in the strength of the colony is evident. After a time an irregularity in the appearance of the brood comb is to be seen, the capped and uncapped brood being abnormally distributed with here and there perforated and sometimes sunken caps (Pl. II, A, B, C). Still later the scales are found.

The time at which the various symptoms appear varies. Climatic conditions, the amount of infection present, and the initial strength of the colony are some of the more important factors causing the variations.

Whether a hive which has housed a colony infected with American foulbrood will transmit the disease is a question which has not been altogether solved but in experimental work all hives that have housed such colonies should be disinfected before they are used again. This can be done satisfactorily by flaming the inside of the hive. If gas is available the Bunsen burner is very satisfactory for this purpose. That no fear need be entertained from hives which have been flamed properly is demonstrated by the fact that the disease has not been transmitted by flamed hives in the experiments made in the present studies, although the number of such hives which have been used is large. The length of time that a sirup or honey suspension of American foulbrood spores stands before the inoculation of a colony is made need not be considered in experimental work.

From what is known of American foulbrood its transmission by queens is not to be expected. Two queens from diseased colonies were introduced into healthy ones in October and the colonies were kept under observation until the following July. The disease did not appear in either of them. In a number of instances during the investigations queens from American foulbrood colonies were used to queen nuclei made by division of healthy colonies. These colonies were under observation for weeks or months before they were used for American foulbrood experiments. In no instance was the disease observed to result from the use of these queens. The conclusion is reached, therefore, that for most experimental work at least the possible previous relation of the queen to diseased colonies need not concern one.

The combs from an American foulbrood colony never should be given to a colony which is to be used for experimental purposes.

The bees from diseased colonies may be used again in certain well-selected cases by transferring them to another hive which may be supplied with comb from healthy colonies or with foundation strips or full sheets. To insure that no infection is present a colony treated in this way should be under observation for a considerable period after brood rearing has begun in it before it is used again.

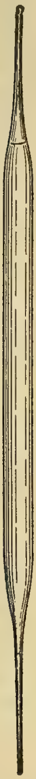

Fig. 8.—Capsule used in determining the thermal death point of spores.

Further reference to the technique used in these studies will be made as the experiments are recorded.

THERMAL DEATH POINT OF AMERICAN FOULBROOD SPORES

In an earlier paper (24) the results from preliminary experiments were given which indicate the amount of heating that is necessary to destroy the spores of American foulbrood when they are suspended in water. The importance of heat as a means for the destruction of these spores in practical apiculture is so great that a further development of the subject during these investigations seemed justifiable.

RESISTANCE OF AMERICAN FOULBROOD SUSPENDED IN WATER TO HEATING

In preparing the spore material for heating a much diluted aqueous suspension of the disease material is drawn into capsules (fig. 8) made from glass tubing of small bore. After being sealed in a flame they are immersed in a water bath having a temperature and for the period desired in the heating.[1] Cultures then are made using a loopful of the suspension from the capsule and brood-filtrate-egg-yolk-suspension agar.

The results of the experiments given in the following table indicate the approximate amount of heating that is necessary for the destruction of the spores suspended in water.

TABLE I.—*Preliminary experiments indicating the thermal death point of the spores of Bacillus larvae suspended in water* [2]

FIRST SET OF EXPERIMENTS. DISEASE MATERIAL RECEIVED FROM AMERICA

Temperature.		Period of heating.	Results as shown by cultures, October, 1913.
°C.	*°F.*	*Minutes.*	
0	0	0	Numerous spores alive (check).
90	194	20	Many spores not killed.
94	201	10	One spore not killed.
96	205	10	All spores killed.
97	207	10	Do.
98	208	10	Do.
99	210	10	Do.
100	212	5	Do.
100	212	10	Do.

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[1] About two minutes are allowed for the suspension within the capsule to reach the temperature of the water outside before time is reckoned.

[2] Fractions are omitted in this paper, the nearest whole number being given.

SECOND SET OF EXPERIMENTS. DISEASE MATERIAL RECEIVED FROM ENGLAND.

Temperature.		Period of heating.	Results as shown by cultures, October, 1913.
°C.	*°F.*	*Minutes.*	
0	0	10	Numerous spores alive (check).
91	196	10	Spores not killed, about $\frac{1}{10}$ as many as in check.
95	203	10	All but 2 spores killed.
96	205	10	All spores killed.
98	208	10	Do.
99	210	10	Do.
100	212	1	Spores not killed, about $\frac{1}{4}$ as many as in check.
100	212	2	All but 100 spores killed.
100	212	3	All but 20 spores killed.
100	212	4	Do.
100	212	5	Do.

THIRD SET OF EXPERIMENTS. DISEASE MATERIAL RECEIVED FROM FRANCE.

Temperature.		Period of heating.	Results as shown by cultures, October, 1913.
°C.	*°F.*	*Minutes.*	
0	0	10	Numerous spores alive (check).
90	194	10	Spores not killed, almost as many as in check.
92	198	10	Spores not killed, about $\frac{1}{4}$ as many as in check.
93	199	10	All but 30 spores killed.
94	201	10	All but 100 spores killed.
96	205	10	All but 12 spores killed.
98	208	10	All but 1 spore killed.
99	210	10	All spores killed.

FOURTH SET OF EXPERIMENTS. DISEASE MATERIAL RECEIVED FROM CUBA.

Temperature.		Period of heating.	Results as shown by cultures, January, 1915.
°C.	*°F.*	*Minutes.*	
92	198	10	Numerous spores not killed.
93	199	10	Do.
94	201	10	Fewer spores not killed.
95	203	10	Do.
96	205	10	Do.
97	207	10	Fewer alive than at 96° C.
98	208	10	Fewer alive than at 97° C.
99	210	10	About 12,000 spores not killed.
100	212	10	About 200 spores not killed.
100	212	11	Do.
100	212	12	Do.

From Table I it will be observed that all the spores taken from the American sample were killed by heating at 96° C. for 10 minutes; that all of those from the English sample were also killed at 96° C. in 10 minutes; that all of those from the French sample were killed at 99° C. in 10 minutes; and that all of those from the Cuban sample were killed at 100° C. in 11 minutes. Spores from the different samples varied, therefore, in their resistance to heating, those from the American and English samples being slightly less resistant than those from the French one which showed in turn slightly less resistance than those from the Cuban sample.

By a comparison of the results it will be observed that many spores among those heated were destroyed at 90° C. in 10 minutes and that the percentage remaining alive when the higher temperatures were used rapidly decreased. The results indicate also that by increasing the temperature the time required to destroy the spores is decreased and vice versa.

Further studies relative to the thermal death point of the spores were made on disease samples received from different localities in the United States. The technique followed is similar to that given on page 22. The results obtained are summarized in Table II:

TABLE II.—*Variation in thermal death point of American foulbrood spores from different localities in the United States*[1]

Temperature.		Period of heating.	Source of samples.										
			Wash.	Minn.	Nebr.	Ohio.	Ill.	Colo.	Wis.	Penn. 4529.	Penn. 4507.	Ohio 4519.	Mont.
° C.	*° F.*	*Minutes.*											
100	212	10	−	−	+	+	+	+	+	+	+	+	+
100	212	5	−	−	−	−	−	−	+	+	+	+	+
100	212	1	−	−	−	−	−	−	−	−	−	−	−
98	208	10	−	−	−	−	−	−	+	+	+	+	+
95	203	10	−	−	−	−	−	−	−	−	−	−	−

[1] The minus sign in Tables II and IV indicates that the spores were not all killed and the plus sign that all of them were killed.

The results in Table II show that in none of the 11 cases were all of the spores killed in 1 minute at 100° C.; in 5 of the cases they were all killed in 5 minutes at this temperature while in 6 of them they were not. In two instances out of the 11 they were not killed in 10 minutes at 100° C. They were killed, however, at this temperature in 11 minutes. It will be seen also that in no instance were all of the spores killed at 95° C. in 10 minutes, but in 5 of the 11 cases all of them were killed at 98° C. within the 10 minutes.

By these results it is shown again that the spores of different samples do vary in their resistance to heat. No conclusion is drawn regarding the cause, environmental or otherwise, for this variation.

TIME A FACTOR IN THE DESTRUCTION OF AMERICAN FOULBROOD SPORES BY HEAT

Suspensions of scales of American foulbrood in water were heated for different periods at 100° C. In the following table are recorded the results obtained when the spores from the Cuban sample were used:

TABLE III.—*Period of heating American foulbrood spores a factor when 100° C. is used*

Temperature.		Period of heating.	Results as shown by cultures, February, 1915.
° C.	*° F.*	*Minutes.*	
100	212	0	25,000 spores present (estimated).
100	212	1	4,000 spores not killed (estimated).
100	212	5	148 spores not killed.
100	212	6	220 spores not killed.
100	212	7	248 spores not killed.
100	212	8	44 spores not killed.
100	212	9	7 spores not killed.
100	212	10	14 spores not killed.
100	212	11	All spores killed.
100	212	12	Do.
100	212	13	Do.
100	212	14	Do.
100	212	15	Do.

From Table III it will be noted that there were about 25,000 colonies in the check cultures. When a similar suspension was heated only about 4,000 spores remained alive after 1 minute at 100° C., 148 after 5 minutes, 44 after 8 minutes, 14 after 10 minutes, and none after 11 minutes. The conclusion is reached, therefore, that the time element is a factor in the destruction of the spores of American foulbrood by heat.

These results further show that the spores of different samples vary in their resistance to heat. It is interesting to note that by heating the disease material at 100° C. for one minute, more than 80 per cent of the spores were killed, and in 5 minutes, more than 99 per cent were destroyed.

In Table IV are summarized results which indicate further the value of the time element in the destruction of the spores by heat. In this instance spore material from 6 different localities was used, the heating being done at 95° C. with the spores suspended in water:

Table IV.—*Effect of the time element when 95° C. is used in heating American foulbrood spores*

Temperature.		Period of heating.	Source of samples.					
			Cuba.	Colo.	Ohio 4504.	N. Y.	Ohio 4519.	Minn.
° C.	*° F.*	*Minutes.*						
95	203	12	−	−	−	−	−	−
95	203	15	−	−	−	−	−	−
95	203	20	−	−	−	−	−	+
95	203	40	−	−	+	+	+	+
95	203	50	−	−	+	+	+	+
95	203	60	+	+	+	+	+	+

From Table IV it will be observed that the spores from all of the six samples studied resisted in an aqueous suspension a temperature of 95° C. for 15 minutes. Spores from the Minnesota sample were destroyed in 20 minutes at 95° C., those from the Ohio and the New York samples in 40 minutes; and those from the Colorado and Cuban samples in 60 minutes. The time element is shown again to be an important factor in the destruction of American foulbrood spores.

These results show also, as was shown above, that the spores contained in different samples vary as to their thermal death point.

Other experiments were made showing the resistance of the spores of *Bacillus larvae* suspended in water to heat. At 93° C. (199° F.) spores from a Minnesota sample were destroyed in one hour, those from a Colorado sample in 1½ hours, while those from the resistant Cuban sample were not all killed in 3 hours. Experiments using Cuban, Colorado, and Pennsylvania samples showed in each instance that numerous spores remained viable after 2 hours' heating at 90° C. (194° F.).

RESISTANCE OF AMERICAN FOULBROOD SPORES TO HEAT WHEN SUSPENDED IN HONEY

The effects of heating American foulbrood spores suspended in water are shown above. When suspended in honey a different degree of resistance is to be expected. The technique used to obtain facts relative to such resistance is quite similar to that described (p. 22) for the experiments in which the spores were heated in aqueous suspensions; instead of water, however, the spores were suspended in honey[1] or honey diluted with water. For testing whether or not the spores had been killed by the heating, cultures were used in some instances and bees in others.

In Table V are summarized some of the results obtained when the spores suspended in honey diluted with an equal volume of water were heated and tested by cultures:

TABLE V.—*American foulbrood spores heated in diluted honey*[1]

Temperature.		Period of heating.	Origin of sample.	Cultural results. April-May, 1915.
° C.	*° F.*	*Minutes.*		
98	208	10	Nebraska	Numerous spores not killed.
98	208	10	New York	Do.
98	208	20	do	Do.
98	208	20	Nebraska	Do.
98	208	20	Illinois	Do.
100	212	10	New York	Do.
100	212	20	do	Do.
101	214	8	Washington State	Do.
101	214	10	Colorado	Do.
102	216	8	Cuba	Do.
103	217	3	Washington State	Do.
104	219	3	do	Do.
105	221	3	Cuba	About 500 spores not killed.

[1] The altitude of the laboratory in Washington being nearly sea level the boiling temperature of water is almost 100° C. The higher temperatures recorded in this table and the following one were obtained by immersing the capsule containing the suspension in a solution of sodium chlorid and other salts.

Table V shows that numerous spores were alive after being heated in a suspension of honey diluted with equal parts of water for 20 minutes at 100° C. The spores of American foulbrood are not destroyed by heat as readily, therefore, when suspended in diluted honey as when suspended in water.

Experiments were made in which the spores were heated suspended in undiluted honey and tested by the cultural method. Table VI indicates the nature of the results obtained:

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[1] The honey used was purchased at the market in sealed cans and was from the crop of the year preceding the experiments.

TABLE VI.—*American foulbrood spores heated in undiluted honey*

Temperature.		Period of heating.	Origin of sample.	Cultural results. April-May, 1915.
°C.	*°F.*	*Minutes.*		
100	212	10	Cuba	Numerous spores not killed.
100	212	10	Washington State	Do.
100	212	10	Ohio	Do.
100	212	20	Cuba	Do.
100	212	20	Washington State	Do.
100	212	20	Ohio	Do.
103	217	25	Washington State	Do.
105	221	20	do	Do.
105	221	20	Cuba	Do.
107	225	20	do	Do.
107	225	30	do	Do.
107	225	40	do	Do.

From the results given in Table VI it will be observed that in every instance the spores suspended in honey resisted 100° C. for more than 10 minutes. It will be noted that numerous spores were alive after being so heated for 20 minutes. In fact they resisted 105° C. for 20 minutes and more. It is shown that numerous spores from the resistant Cuban sample were still alive after 40 minutes heating at 107° C. When suspended in honey, therefore, spores are much more resistant to heat than when suspended in water (p. 22) or when suspended in diluted honey (p. 26).

While the thermal death point has not been definitely determined for the spores suspended in honey, the results obtained indicate that the point was being approached by the experiments of Table VI. It was found that the spores suspended in honey were killed readily by heating in the autoclave at 15 pounds pressure, being destroyed, in fact, by the time this pressure was reached. In making these tests the suspension in test tubes was brought to 100° C. before being placed in the autoclave. After the heating cultures were made.

SPORES HEATED IN HONEY AND FED TO BEES

A further set of experiments was made in which American foulbrood material suspended in honey was heated to 100° C. and tested by the inoculation of colonies of bees. In performing the experiments a concentrated aqueous suspension of the disease material was added to hot honey, which is handled more readily than the cooler honey, until each 15 c.c. of honey suspension contained the material from 3 to 5 scales. This was then distributed in test tubes, each tube receiving about 15 c.c. of the suspension. These tubes were heated as were the aqueous suspensions in experiments reported above (p. 22), by immersing them in water. After heating, the contents of the tube were added to sirup and colonies were inoculated. In Table VII some of the experiments performed are summarized:

TABLE VII.—*American foulbrood spores heated in honey and fed to bees*

Date of inoculation.	Temperature.		Period of heating.	Results of inoculation.
1916	*° C.*	*° F.*	*Minutes.*	
Aug. 25	100	212	10	American foulbrood produced.
Sept. 12	100	212	12	No disease produced.
Do.	100	212	15	Do.
Do.	100	212	18	Do.
Aug. 25	100	212	20	Do.
Sept. 12	100	212	25	Do.
Aug. 11	100	212	30	Do.
Aug. 25	100	212	30	Do.
Do.	100	212	45	Do.
Oct. 11	100	212	90	Do.
Do.	100	212	120	Do.

It will be noted from Table VII that American foulbrood was produced after the scale material had been heated in honey for 10 minutes at 100° C., but was not produced when this temperature was maintained for 12 minutes or longer. The amount of heating required to prevent American foulbrood in the experiments recorded in this table is not as great as might have been expected from an examination of Table VI. The results tend to indicate that the virulence might have been affected somewhat before the spores were killed. Sufficient data to prove the point, however, are yet lacking.

From the various experiments relating to the thermal death point of American foulbrood spores recorded on the foregoing pages, it will be observed that 100° C. maintained for 10 minutes, with an exception now and then, is sufficient to kill all of the spores when suspended in water. It will be observed also that 98° C. applied for 10 minutes will do this in many instances and that 95° C. is sufficient in some cases. It is shown, furthermore, that a large majority of the spores are killed at 90° C. in 10 minutes and also that a very large number of them are killed at 100° C. in 1 minute.

That a difference exists in the thermal death point of American foulbrood spores was expected. A difference is seen in the spores from different samples, in those from different larvæ or pupæ in the same sample, and indeed in those of the same larvæ or pupæ. The maximum difference, when expressed in terms of degrees of temperature, between the most resistant spores of any two samples among those studied, the temperature being maintained for 10 minutes, is approximately 7° C.; and when expressed in time, the temperature being maintained at 100° C., is approximately 7 minutes. These differences are for the spores suspended in water. Suspended in honey a greater difference is to be expected. That still greater variations exist than those observed in these studies is most certain. To meet such differences the beekeeper has been urged to employ for the destruction of the spores in practical apiculture somewhat more heat than the minimum amount that is required as determined by experimental studies.

RESISTANCE OF AMERICAN FOULBROOD SPORES TO DRYING

That the American foulbrood spores are able to withstand much drying has long been realized by beekeepers. Scales of American foulbrood obtained in 1907 from colonies in which the disease had been produced through experimental inoculation were stored in the laboratory. Each succeeding year for 9 years tests were made relative to the viability of the spores in this material. In 1916 they were still alive and as resistant to heat and as virulent as at any previous time. It is most likely that they would have withstood the drying at room temperature for a very much longer period than the 9 years.

RESISTANCE OF AMERICAN FOULBROOD SPORES TO DIRECT SUNLIGHT

RESISTANCE OF AMERICAN FOULBROOD SPORES WHEN DRY TO DIRECT SUNLIGHT

In conducting experiments relative to the resistance possessed by spores of *Bacillus larvae*, when dry, to the direct rays of the sun, a heavy aqueous suspension is made of the scale material. This is spread in a thin film in Petri dishes and allowed to dry, the amount of disease material in each dish being equal to that in from 3 to 5 scales. The dry layer of disease material is then exposed to the direct rays of the sun and after different intervals of time cultures are made to determine whether the spores are viable. Table VIII gives a summary of the experiments made:

TABLE VIII.—*Resistance of spores of Bacillus larvae when dry to the sun's rays*

Date of experiment.	Period of exposure	Results as shown from cultures.
1916	*Hours.*	
Aug. 31	2	Numerous spores not killed.
Aug. 28	4	Many spores not killed.
Sept. 5	5	Do.
Do.	7	Several spores not killed.
Do.	10	Few spores not killed.
Sept. 6	11	Do.
Sept. 28	12	Many spores not killed.
Sept. 19	29	Several spores not killed.
Sept. 25	38	A dozen spores not killed.
Aug. 23	28	All spores killed.
Aug. 28	37	Do.
Sept. 23	41	Do.
Sept. 25	41	Do.
Sept. 16	44	Do.
Do.	61	Do.
Sept. 25	79	Do.

From Table VIII it will be observed that all of the spores were killed by the direct rays of the sun in from 28 to 41 hours. It is natural to expect that the period required would depend upon the date and time of exposure and somewhat upon the thickness of the film of disease material exposed. The climatic conditions during August and September, the time of the experiments, were naturally favorable for the destruction of bacteria by sunlight. The exposures were made only when the sky was clear, preference being given to the middle portion of the day.

REISISTANCE OF AMERICAN FOULBROOD SPORES WHEN SUSPENDED IN HONEY TO DIRECT SUNLIGHT

The technique used is as follows: A concentrated aqueous suspension of spore-containing material is added to honey in Petri dishes, each dish receiving the disease material equal to that of from 3 to 5 scales. These are exposed to the direct rays of the sun. The tops are used with the dishes to prevent robbing by bees. After different periods of time the contents of a single dish are added to sirup and fed to a colony free from disease. A set of experiments made is summarized in Table IX.

TABLE IX.—*Spores of American foulbrood in honey exposed to the sun*

Date of experiment.	Period of exposure.	Results of inoculation.
1916.	*Hours.*	
July 13	6	Large amount of American foulbrood produced.
July 15	13	Moderate amount of disease produced.
	Weeks.	
July 26	2	Scattering cells of diseased brood.
Aug. 25	4	Considerable diseased brood.
Sept. 1	5	Do.
Aug. 10	4	No disease produced.
Aug. 18	5	Do.
Sept. 14	6	Do.
Do.	8	Do.

The data given in Table IX show that the spores of American foulbrood when suspended in honey were destroyed by the direct rays of the sun in from 4 to 6 weeks. As the suspension in each dish contained the disease material of from 3 to 5 scales it is evident from the results obtained that many of the spores must have been destroyed in a comparatively short period.

It will be readily appreciated that here again the period required for the destruction of the spores will vary greatly with the intensity of the sun's rays to which the honey suspension is subjected. In these preliminary experiments the period of exposure represents the entire time from the beginning of the exposure to the time of inoculation. There were days during the exposure on which the sun shone a great deal, others on which it shone very little, and still others on which it did not shine at all. The comparatively low temperature of the honey suspension attained during the exposure to the sun could not have been an important factor in the destruction of the spores.

RESISTANCE OF AMERICAN FOULBROOD SPORES TO FERMENTATION

A few preliminary experiments relative to the effect of fermentative processes on the spores of American foulbrood were made. The processes involved concern chiefly the sugar splitting and the proteolytic enzymes. In experiments relative to the former, the scale material was suspended in a 20 per cent aqueous solution of honey and, in those relative to the latter, it was suspended in a 1 per cent aqueous solution of peptone. In each case a small bit of soil was added to inoculate the suspending solution still further. These suspensions, respectively, were distributed in test tubes and allowed to undergo fermentation. Observations were made at incubator and outdoor temperatures. The outdoor temperature was that which obtained in an empty hive body covered, and standing in the apiary at the time of the year shown by the dates of the experiments. After intervals reckoned in days colonies free from disease were inoculated, each with a suspension from a single tube. The experiments are summarized in Table X:

TABLE X.—*Resistance of the spores of Bacillus larvae to fermentation*

Date of experiment.	Nature of the suspension.	Period.	Temperature.	Results of inoculations.
1916.		*Days.*		
Aug. 14	Honey	26	Outdoors	American foulbrood produced.
Sept. 9	do	53	do	Do.
Aug. 11	do	24	Incubator	Do.
Sept. 9	do	53	do	Do.
Aug. 14	Peptone	26	Outdoors	Do.
Sept. 9	do	53	do	Do.
Aug. 11	do	24	Incubator	Do.
Sept.	do	53	do	Do.

From Table X it will be seen that in the presence of fermentative processes in the honey solution and in the peptone solution the spores were alive and virulent after 53 days at incubator and at outdoor temperatures. It is quite probable that they would have remained so for a very much longer period.

RESISTANCE OF AMERICAN FOULBROOD SPORES TO CHEMICAL DISINFECTANTS

While a mass of data was obtained relative to the effect of chemical agents on the spores of American foulbrood, the results are still considered as being preliminary in nature. In conducting the experiments a suspension of disease material in an aqueous solution of the disinfectant was used. This was drawn into capsules [1] (fig. 9) and sealed. After different intervals of time the suspension was cultured, using brood-filtrate-egg-yolk-suspension agar.

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[1] The ampules used are made from glass tubing of small bore by heating and drawing it into three bulbs. The two intermediate constricted portions are wrapped with cotton. After being sterilized the ampules are filled with the spore-containing suspension sealed and placed at different temperatures. Incubator, room, and outdoor temperatures were employed. At the time of making the cultures the ampule is broken at the two intermediate constrictions and the spore-containing suspension used in making the inoculations is obtained from the intermediate bulb. By this method an immersion of the spores in the solution for the entire period is assured.

The results show that spores of American foulbrood were alive after being in suspension in 1, 2½, and 5 per cent aqueous solutions of carbolic acid (commercial) for months at room, outdoor, and ice-box temperatures, respectively. The maximum period during which any suspension was kept at ice-box temperature was 32 months. At incubator temperature the period during which the spores remain alive in 5 per cent carbolic acid is better reckoned in weeks than months. In 5 and 10 per cent solutions, respectively, of formalin (37 per cent formaldehyde) it was found that they were viable after 6 hours, and in a 20 per cent solution they were alive after 30 minutes. While the spores were alive in the formalin suspensions after these periods, the evidences obtained indicate that the chemical death point was being reached. Mercuric chlorid was resisted for days in 1 to 1000 and 1 to 500 solutions, respectively.

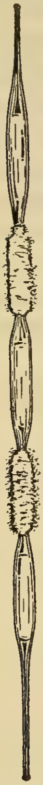

FIG. 9.—Capsule used in determining the resistance of spores to chemical disinfectants.

Inasmuch as the spores of American foulbrood resist the action of carbolic acid for more than a month under fairly favorable conditions for their destruction, this agent could scarcely be used with profit in practical apiculture. As the destruction of the spores with formalin is a question of hours only, it is possible in well-selected cases that use could be made of this agent. Since mercuric chlorid in strengths ordinarily used is resisted by the spores for days and furthermore is such a violent poison, its value as a disinfectant in American foulbrood is evidently limited. The general conclusion in regard to chemicals as disinfectants is, therefore, that they offer very little promise as a practical means for the destruction of the spores of American foulbrood.

EFFECT OF DRUGS ON AMERICAN FOULBROOD

Divers experiences have been reported by beekeepers relative to the value of drugs in the treatment of the bee diseases. The fact that the spores of *Bacillus larvae* possess a marked resistance to chemical disinfectants tends to discourage hope that such substances would be of much therapeutic value when employed as drugs in American foulbrood. Such a conclusion, naturally, would not follow necessarily. Some data relative to the effects of drugs on this disease have been obtained through experimental inoculations using beta-naphthol, U. S. P.; carbolic acid (phenol), C. P.; oil of eucalyptus,

U. S. P.; formic acid, C. P.; salicylic acid, U. S. P.; salol (phenyl salicylate, U. S. P.); and quinin (bisulphate of quinin, U. S. P.).

In making the inoculations a suspension of scale material in water is added to medicated honey and colonies free from the disease are fed. The different drugs are used in different proportions. Honey, rather than sirup, is employed since the bees will take the drugs in higher proportions when in honey than when in sirup. The strength that they will take varies somewhat with the conditions present. The higher proportions recorded in Table XI summarizing the experiments approximate the maximum amount that can be employed:

TABLE XI.—*Indicating the effect of drugs on American foulbrood*

Date of experiment.	Drugs.	Strength.	Results of inoculation.
1916.			
July 11	Betanaphthol	1:2000	American foulbrood produced.
May 29	.....do	1:1000	
June 5	.....do	2:1000	
July 11	Carbolic acid	1:2000	
June 20	.....do	1:1000	
Do..	.....do	2:1000	
May 29	.....do	10:1000	
Do..	Oil of eucalyptus	4:1000	
July 11	Formalin	3:1000	
Do..	Salicylic acid	1:2000	
May 29	.....do	1:1000	
June 5	.....do	2:1000	
July 11	Salol	1:2000	
May 29	.....do	1:1000	
June 5	.....do	2:1000	
July 11	Quinin	2:1000	
May 29	.....do	3:1000	
June 5	.....do	10:1000	

From Table XI it will be seen that American foulbrood was produced in all cases in which colonies were fed a suspension of diseased material in honey medicated with betanaphthol, carbolic acid, eucalyptus, formic acid, salicylic acid, salol, and quinin respectively in the proportions noted. In some of the experiments medicated sirup free from the spores was fed to the inoculated colony on a few successive days following the inoculation, and in some instances both preceding and following it. Whether these treatments with the medicated sirup produced any effect on the infection—positive or negative—was not determined definitely.

The results thus far obtained indicate that the drugs cited here can not be depended upon, for the present at least, in the treatment of American foulbrood. They do not preclude the possibility, however, that other drugs might be used with profit, but they do emphasize the fact that beekeepers should make sure that the value of a drug has been clearly demonstrated before it is used.

The results recorded on the foregoing pages relative to the resistance of American foulbrood spores to heat, drying, fermentation, sunlight, chemical disinfectants, and drugs, it will be observed, are only approximate from a strictly technical viewpoint. For practical purposes, however, they are in most instances entirely adequate. In using any of these results in devising means for the destruction of the spores in practical apiculture the time element determined by the experiments should be somewhat increased in each instance.

MODES OF TRANSMISSION

Observations made during these studies point to certain paths by which American foulbrood is most likely to be transmitted. The evidences obtained tend to support certain views which have been entertained by beekeepers and to negative others which have been suspected by some as possible. Inasmuch as the disease may be produced in larvæ by feeding a colony *Bacillus larvae* in pure cultures, or from decaying remains of brood dead of the disease, it would seem that the portal of entry of the virus is somewhere along the alimentary tract of the larva. The fact leads at once to the suspicion that the food of bees contaminated with disease material is a very probable source of infection. Were the water supply likewise contaminated naturally it also would be a probable source of infection. Two prerequisites for the appearance of American foulbrood in a colony are (*a*) larvæ of the feeding age, and (*b*) a sufficient amount of disease material in the food or water supply of bees. A small amount of brood or a heavy flow of nectar, therefore, would tend to reduce the likelihood of colony infection under conditions otherwise favorable for infection.

Bees manifest a tendency to remove brood dead of American foulbrood as shown by the remains of partially removed larvæ and pupæ dead of the disease. The removal is done piecemeal and is accomplished more readily when the brood is recently dead than when the decaying remains are at all viscid or dry. Were the fate of the removed fragments definitely known much more could be said concerning the spread of the disease in the colony. It has been observed that a small amount of infection—a dead larva or pupa here and there—may be present in a colony for months, a year, and even longer, without causing a heavy infection in it. There is considerable evidence to support the belief that occasionally in cases of light infection the disease may disappear unaided by treatment. Such a phenomenon frequently takes place in sacbrood and indeed should be expected to occur now and then in American foulbrood. It should be emphasized that such a course for the disease, if it occurs at all, is unusual. Although American foulbrood usually spreads more or less rapidly within an infected colony, the fact remains that it frequently does not.

It was observed that many diseased colonies could be present in the experimental apiary without causing the infection to be transmitted to other colonies in the apiary. This fact is naturally very significant. On account of it certain views concerning the manner of transmission of the disease, which might otherwise be regarded as probable, are rendered untenable. If flowers visited by bees from infected colonies, and later by bees from healthy ones, are a likely source of infection, or if the water supply is such a source, or if drones are a means by which the disease is likely to be transmitted, there would have been a different observation to report.

In a few instances in the experimental apiary colonies near heavily infected ones became infected. That the disease may have been transmitted through the drifting or accidental straying of bees is one of the possible explanations for the disease in these cases. That a slow form of robbing might have taken place should be considered also as a possible explanation in these cases.

Brood comb containing brood dead of American foulbrood will transmit the disease when placed in a hive containing a healthy colony. The likelihood that the disease will be transmitted by combs from diseased colonies, which contain honey but no brood, probably is frequently overestimated. It would seem that a spread of the disease in this way would depend considerably upon the amount of infection that was present in the colony from which the combs were removed. This would depend also somewhat upon the presence or absence of brood in the colony to which the combs were given. Sufficient facts are wanting to make definite statements in regard to the probability of infection in such cases. Robbing material containing the spores of American foulbrood from any source is likely to transmit the disease although it does not necessarily do so.

How often the disease would be transmitted through the medium of hives which have housed infected colonies, if used without flaming, has not been definitely determined. Experimental colonies have been placed in such hives and kept in them for a year with the result that no disease appeared.[1] It probably will be found that in many cases the treatment of the hive bodies is not necessary to insure that the disease will not be transmitted by them. From the results obtained by practical apiarists and by observation made in the experimental apiary during these studies the fact has been well established, however, that the danger of infection from such hives is entirely removed by carefully flaming them inside. The destruction of the hive is, therefore, never necessary. Chemical disinfectants should not be relied upon for the destruction of the spores of American foulbrood as the spores possess a marked resistance to these agents. If any chemical is used, however, strong solutions of formaldehyde would seem to offer some promise of being efficient.

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[1] An experiment in which four colonies were used, was made as follows: The insides of the top and bottom board of each of two hive bodies were washed with an aqueous suspension of spore-containing material and allowed to dry, and the inside of the walls of each of two others were similarly washed and allowed to dry. Colonies were transferred to these four hives during the summer. American foulbrood appeared in the two colonies housed in hives of which the tops and bottoms had been contaminated with disease material but did not appear in the other two. These results, naturally, are not conclusive but they are suggestive.

After disease material is removed from the hive by bees and is released from them the chances that a bee will come in contact with the contained spores again is comparatively slight. Furthermore such spores must withstand certain agencies in nature which tend to destroy them, thus decreasing the chances still further that disease will result from them. If exposed to the direct rays of the sun the spores will be destroyed more or less readily (p. 29). Much less is to be expected from fermentation (p. 31) or drying (p. 29). Should the spores reach the soil or running water the likelihood that bees will come in contact with them and carry them to the feeding brood is indeed slight. Should the spores reach the water supply of the bees and should this supply be a stagnant or slow-moving body of water, the chances naturally would be somewhat increased.

Experiments in which queens taken from diseased colonies were introduced into healthy ones were not kept under observation for a sufficiently long period to justify a definite conclusion as to the probability of the disease being transmitted by such queens, but the data secured indicate strongly that the danger of transmission in this way has been overestimated at times. The favorable results obtained by beekeepers using the shaking treatment should tend to allay fear in regard to the transmission of the disease by this route. Indeed the facts thus far obtained suggest that the transmission of the disease by way of the queen should not be expected.

The spread of the disease by means of the clothing or hands of the apiarist is not to be feared especially. The hive tool, if brought in direct contact with dead larvæ in testing for the presence of disease, might serve to transmit infection, but during the usual manipulations it would not. The practice sometimes followed by beekeepers of thrusting the hive tool into the soil to clean it would seem to be a safe procedure. Washing the hands with water instead of disinfectants is more convenient and is sufficient. Reasonable care should be taken, of course, that the water used does not become or reach the water supply of bees.

DIAGNOSIS

American foulbrood is the easiest of the brood diseases to diagnose. Methods by which this can be done in the laboratory are given in an earlier publication (16). The diagnosis as a rule can be made from the symptoms (p. 5) alone. No helpful sign is found in the appearance of the adult bees. A weak colony justifies a suspicion that a disease is present. In American foulbrood, as in European foulbrood and sacbrood, a sample suitable for diagnosis must contain the remains of brood dead of the disease.

The colony symptoms which are usually adequate for a definite diagnosis of American foulbrood are the following: The death of larvæ in capped cells after the endwise position has been assumed (Pls. I, II, III, VI), and the death of pupæ soon after transformation (Pls. IV, V, VI), the brown shade of dead brood, the viscidity (ropiness) of the decaying remains, the character of the scales, and the foulbrood odor.

BACTERIOLOGICAL EXAMINATION

A conclusive diagnosis of American foulbrood can always be made from a bacteriological examination of brood dead of the disease. With gross characters suggesting the disease the experienced can frequently make the tentative diagnosis definite by a water mount made from the decaying brood remains, or the scales. A very large number of spores free from rods with no other bacterial species present is the characteristic microscopic picture in the disease. The spores are those of *Bacillus larvae* (fig. 4; Pl. VII, B, D). As a rule, a stained preparation does not furnish much additional aid. In all cases of doubt cultures (agar plates are satisfactory) should be made. The absence of growth on the plates when the other data strongly suggest American foulbrood is sufficient for a positive diagnosis. In routine work the cultures should always be made. Occasionally further evidence that the spores present are those of *B. larvae* is desired. This can be obtained by the employment of methods and media given in this paper (p. 17).

DIFFERENTIAL DIAGNOSIS

EUROPEAN FOULBROOD

European foulbrood can be recognized (27) in most instances by the death of brood in uncapped cells, the yellow hue of larvæ recently dead changing later often to a brown, and an absence of the foulbrood odor. In cases in which these younger larvæ have been removed, the diagnosis of European foulbrood can very often be made from the remains of brood which has died in capped cells. In these cases the remains of dead larvæ and not of pupæ are encountered. These decaying masses pass through a stage at which they are somewhat viscid. The scales are rubberlike[1] in consistency. In these masses and in the scales large numbers of *B. alvei* are found.

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[1] The term "rubberlike" needs interpretation. When applied to the scales of European foulbrood it means simply that they are less brittle than either those of American foulbrood or sacbrood. The property "elasticity" as usually thought of in common parlance in connection with rubber is not meant.

SACBROOD

Sacbrood is recognized (25) by the death of larvæ in capped cells and not of pupæ, by the saclike appearance of the dead remains, and by the absence of viscidity. The absence of microorganisms in the remains characterizes the microscopic picture.

OTHER CONDITIONS

Other brood conditions referred to as chilled brood, overheated brood, starved brood, and in some cases drone brood, must be differentiated from American foulbrood. The history of the case, the age of the brood at the time of death, and the absence of ropiness and of the foulbrood odor, usually make the diagnosis comparatively easy.

In some of the disorders of adult bees excrement of the adult bees is sometimes found in the cells of the brood combs. When dry the masses resemble somewhat brood-disease scales. The character of the masses together with the microscopic picture is usually sufficient for a diagnosis. In these cases a stained preparation is preferable. The fecal matter contains bacterial rods in large numbers. In all of these conditions the absence of *B. larvae* furnishes definite evidence that American foulbrood is not present.

PROGNOSIS

Without treatment the prognosis in American foulbrood is decidedly grave, the rule being that the colony sooner or later dies as a result of the disease. This is true for experimental colonies and is true also, as has been proved by the experiences of beekeepers, for colonies in which the disease has occurred through natural means.

A colony heavily inoculated experimentally is not destroyed by disease in one month or two months. Loss in strength may be apparent, however, after one month. If a colony is inoculated early in the season and is heavily infected, it may die by midsummer; if less heavily infected, it may live longer but die later in the season. The infection may be so slight, indeed, that the colony may not be destroyed directly but be so weakened that it will die during the winter or surviving emerge a weakened colony in the spring and then die of the disease during the following bee season. When a colony during the summer contains much dead brood and becomes very weak as a result of the disease, it usually absconds. The queen is to be found among the bees to the last, and stores are not wanting as a rule.

A question of considerable interest but one which has not yet been completely answered is: Does an American foulbrood colony ever recover without treatment? Some beekeepers have entertained the belief that occasionally it does. Experimental evidence indicates that it probably does. Colonies in the experimental apiary, with a larva or pupa dead of the disease here and there only, certainly did not become badly diseased for more than a year and apparently recovered. To have proved conclusively, however, that such colonies were completely free from possible infection from within would have necessitated observations over a much longer period.

It is known that worker, drone, and queen larvæ die of the disease. Theoretically it is possible that a colony might become queenless as a direct result of American foulbrood but care must be taken in attributing this condition to the disease, for very often queens are reared in diseased colonies, and to all appearances are healthy. Whether a larva once infected ever recovers from the disease is not known.

From the facts at hand it may be concluded, therefore, that the prognosis in American foulbrood in an untreated colony is especially grave. From the practical viewpoint, at least, complete recovery from the disease without treatment, if it occur at all, should be considered for the present to be the exception. While an infected colony may live for a long time and yield a profitable surplus for a considerable period, this is not the rule; more often the course of the disease is comparatively short, and the destruction of the colony the outcome.

SUMMARY AND CONCLUSIONS

A brief summary of facts known about American foulbrood together with a few conclusions drawn from them are given here. Some of the facts have been known for many years, others are of more recent origin, and still others are new. All of them are supported by experimental studies recorded in the present paper.

1. American foulbrood is an infectious disease of the brood of bees caused by *Bacillus larvae*.
2. All larvæ—worker, drone, and queen—are susceptible to the infection; adult bees are not.
3. Man evidently is not susceptible to infection with the organism nor are the experimental animals.
4. So far the disease has not been encountered or produced in other insects than honeybees.
5. The brood of bees can be infected through feeding the spores of the bacillus to a colony.
6. The spores contained in a single scale are more than enough to produce considerable disease in the colony.
7. The portal of entry of the infecting agent is somewhere along the alimentary tract of the larva, most likely the stomach (mid-intestine).

8. Practically speaking there are no secondary invaders either during the life of the infected larva or during the decay of the remains.

9. The incubation period is approximately 7 days.

10. The brood is susceptible to infection at all seasons of the year.

11. More brood dies of the disease during the second half of the brood-rearing season than during the first half.

12. The disease is present at least in Australia, New Zealand, Denmark, England, Ireland, Germany, France, Switzerland, Canada, Cuba, and the United States. The ropy foulbrood of all these countries is one and the same disease.

13. Occurring as it does in such a wide range of climatic conditions, it is evident that the presence of the disease can not be attributed alone to any particular climate.

14. The course of the disease in the colony is not affected greatly, if at all, by the quality of food used by the bees, or by the quantity present.

15. Colonies in which the disease has been produced through artificial inoculation can be kept in the experimental apiary without transmitting the disease to others. This fact is of special importance not only in the technique of making studies, but also in the control of the malady.

16. The spores of American foulbrood remain alive and virulent for years in the dry remains (scales) of larvæ and pupæ dead of the disease and in cultures that have become and remain dry.

17. The spores are very resistant to most destructive agencies. A variation in resistance is noted both as to the individual spores of a sample and as to the spores contained in different samples.

18. Many of the spores are killed within 1 minute at 100° C. and all of them from some samples are killed in less than 5 minutes. In some instances 96° C. maintained for 10 minutes will destroy all of the spores while 98° C. will often do it. The most resistant of the spores studied when suspended in water have not withstood 100° C. for 11 minutes.

19. The spores withstand more heating when they are suspended in honey or honey diluted with water than when suspended in water.

20. The spores suspended in honey or diluted honey can be destroyed by 100° C. but it may require half an hour or more to do so.

21. American foulbrood spores when dry were destroyed by the direct rays of the sun in from 28 to 41 hours.

22. The spores when suspended in honey and exposed to the direct rays of the sun were destroyed in from 4 to 6 weeks.

23. The spores when suspended in honey and shielded from direct sunlight remained alive and virulent for more than a year. It

is very likely that they are capable of remaining so for a very much longer period.

24. The spores resisted the destructive effects of fermentation for more than 7 weeks at incubator and outdoor temperatures, respectively, and probably are able to withstand these agencies for a very much longer period.

25. The spores resist carbolic acid at room temperature in strengths ordinarily used as a disinfectant for periods of months; 1 to 1000 mercuric chlorid for days; 10 per cent formalin for hours.

26. Experiments recorded in the present paper indicate that drugs do not materially affect the course of the disease.

27. American foulbrood infection is transmitted primarily through the food of bees; possibly at times to some extent through their water supply. Robbing from the diseased colonies of the apiary, or from neighboring apiaries, is the most likely mode by which the disease is transmitted in nature.

28. The placing of brood combs containing diseased brood with healthy colonies will result in the transmission of the disease.

29. Flowers should not be considered as a likely medium through which infection may take place.

30. Whether the disease is ever transmitted by queens or drones has not been determined. That they have been overestimated at times as possible sources of infection seems likely.

31. It is quite probable that in many cases hives which have housed colonies infected with American foulbrood will not transmit the disease to healthy colonies transferred to them. Results from the present studies confirm the observation made by beekeepers that danger from this source may be removed by properly flaming such hives inside.

32. The clothing of those about an apiary, and the hands of the apiarist are not fruitful sources for the transmission of the disease.

33. Tools and bee supplies generally about an infected apiary will not transmit the infection in the absence of robbing from those sources.

34. American foulbrood usually can be diagnosed from the symptoms alone. A definite diagnosis can always be made from suitable samples by bacteriological methods.

35. The prognosis in the disease in the absence of treatment is decidedly grave but with proper treatment it is favorable.

36. From the technical viewpoint many of the problems considered in these studies have been solved only partially; from the practical point of view, however, the results are sufficient to make a logical, efficient, and economic treatment of American foulbrood possible.

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EXPLANATION OF PLATES

PLATE I

Brood affected with American foulbrood:

A.—American foulbrood produced by the feeding of pure cultures of *Bacillus larvae*, showing the later stages of decay of the brood.

B.—American foulbrood produced experimentally, showing irregular distribution of capped and uncapped cells, punctured caps, and scales.

C.—American foulbrood, showing sunken and punctured caps. The sample was shipped by mail for diagnosis.

PLATE II

Healthy bee larvæ (prepupæ) and first and second postmortem stages of American foulbrood larvæ as described in the present paper:

A.—Cap of cell containing a healthy larva. Being recently constructed, it is convex.

B.—Cap of cell containing a larva recently dead of the disease. It is not unlike many of the caps over healthy larvæ.

C.—Cap of cell containing a diseased larva. It is slightly sunken.

D.—End view of a healthy larva. The cap was removed artificially. (In the laboratory this is done conveniently with fine pointed curved forceps or a dissecting needle.)

E.—End view of larva illustrating the earliest (first) stage of American foulbrood.

F.—End view of larva which has reached the second stage.

G.—Ventral view of a healthy larva of the age at which death from American foulbrood frequently occurs.

H.—Ventral view of larva illustrating the first stage after death.

I.—Ventral view of larva showing second stage.

PLATE III

Third, fourth, and fifth stages of decay in American foulbrood larvæ:

A.—Punctured cap of cell containing a dead larva.

B.—End view of larva illustrating the fourth stage of decay. The cap was removed artificially as indicated by the torn edges.

C.—End view of larva illustrating the fifth stage of decay, the scale. The cap had been removed by the bees, as shown by the smooth condition of the mouth of the cell.

D.—End view of larva, third stage.

E.—End view of larva, fourth stage.

F.—End view of larva, fifth stage—the scale.

G.—Ventral view of larva, third stage.

H.—Ventral view of larva, fourth stage.

I.—Ventral view of larva, fifth stage—the scale.

PLATE IV

Healthy pupæ and first and second postmortem stages of American foulbrood pupæ as described in the present paper:

A.—Healthy pupa of the age at which death from American foulbrood occurs.

B.—End view of pupa, first stage of the disease.

C.—End view of pupa, second stage.

D.—Ventral view of pupa of the age at which death from American foulbrood occurs.

E.—Ventral view of pupa, first stage.

F.—Ventral view of pupa, second stage.

PLATE V

Third, fourth, and fifth postmortem stages of American foulbrood as described in the present paper:

A.—End view of pupa, third stage.

B.—End view of pupa, fourth stage.

C.—End view of pupa, fifth stage—the scale.

D.—Ventral view of pupa, third stage.

E.—Ventral view of pupa, fourth stage.

F.—Ventral view of pupa, fifth stage—the scale.

PLATE VI

Various phases of the appearance of brood dead of American foulbrood:

A.—Larva in cell not yet capped, dead of American foulbrood.

B.—A developing bee dead of American foulbrood immediately before entering the pupal stage.

C.—A punctured cap with two holes.

D.—Larva dead of American foulbrood gnawed and partially removed by the adult bees.

E.—End view of larval scale. The cap was removed artificially.

F.—End view of pupal scale.

G.—Lateral view of healthy larva in capped cell.

H.—Lateral view of larval scale in the cell cut lengthwise. The cap had been removed by the adult bees.

I.—Lateral view of pupal scale in position in cell cut lengthwise.

PLATE VII

Vegetative form, spore formation, spores, flagella, and giant whips of *Bacillus larvae.* Photomicrographs:

A.—Vegetative form from a 24-hour culture on the surface of brood-filtrate agar. × 1000.

B.—Spore formation and spores from the surface of brood-filtrate agar. × 800.

C.—Flagella. Stained by Loeffler's method as modified by Johnson and Mack. × 1000. (Retouched.)

D.—Spores from a stained smear made directly from a decaying larva dead of American foulbrood. × 1000.

E.—The production within the rods of separate elements, each being supplied with flagella. × 1000.

F.—Giant whips and small spherical bodies in the older cultures of *B. larvae* obtained from the water of condensation of a brood-filtrate-agar slant culture. Fixed in 50 per cent formalin and stained with carbol fuchsin. × 1000.

G.—Small and larger giant whips, and spherical bodies similar to those of F. × 1000.

A similarity existing between the microscopic appearance of giant whips and spirochetes caused Maassen (14) to believe them to be spirochetes and to introduce the name *Spirochaeta apis.*

H.—Very large whip, and spherical bodies similar to those of F and G. × 1000.

PLATE VIII

Colonies and cultures of *Bacillus larvae:*

A.—Surface colony and deep colonies as seen in brood-filtrate agar plates.

B.—Surface colony on brood-filtrate agar more highly magnified.

C.—Deep colony in the same medium, magnified.

D.—Surface growth on brood-filtrate-agar slant.

E.—Culture of *Bacillus larvae* in bee-larvæ agar when the Liborius method is used. The growth is throughout the upper third of the medium.

F.—The culture is similar to E but the growth is nearer the surface.

G.—The culture is restricted in the agar and is near to but not at the surface of the medium.

H.—The growth is less restricted in area and farther from the surface than in G.

I.—The growth is very restricted in area and is below the middle of the medium.

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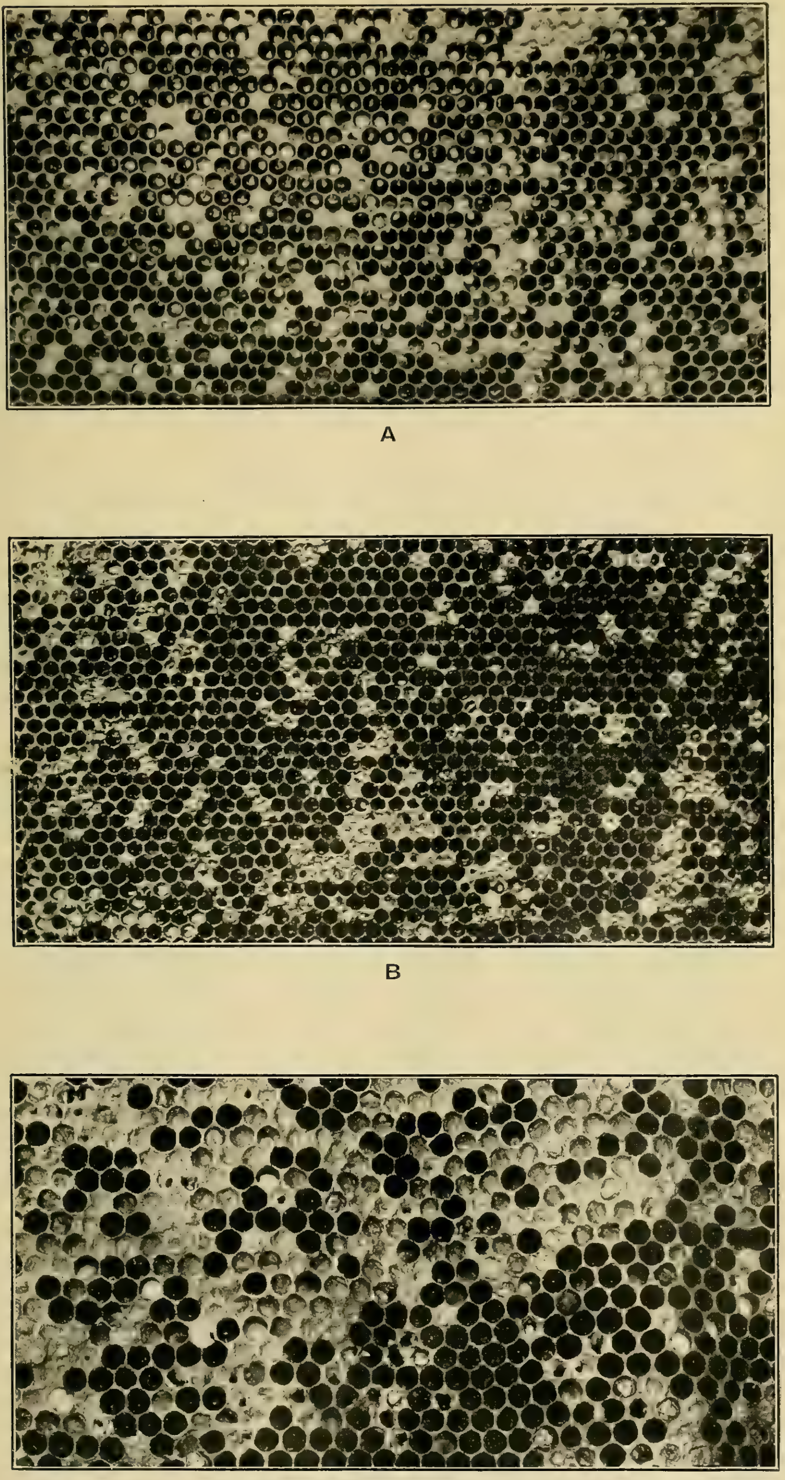

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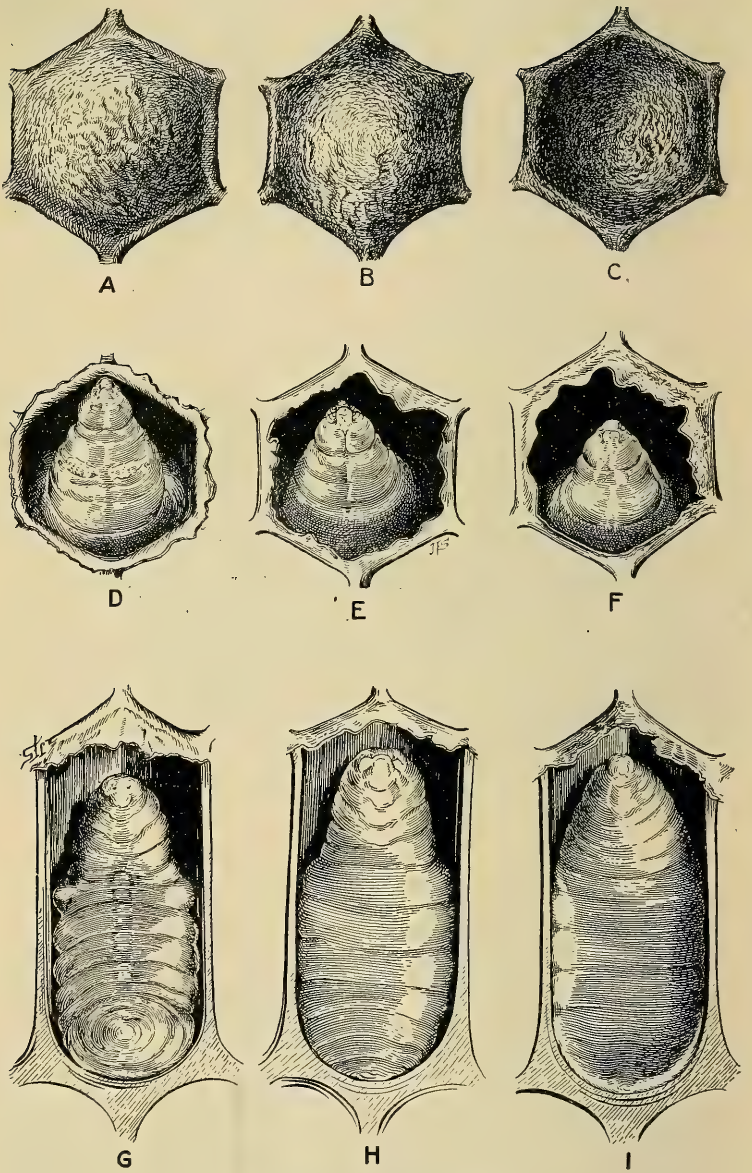

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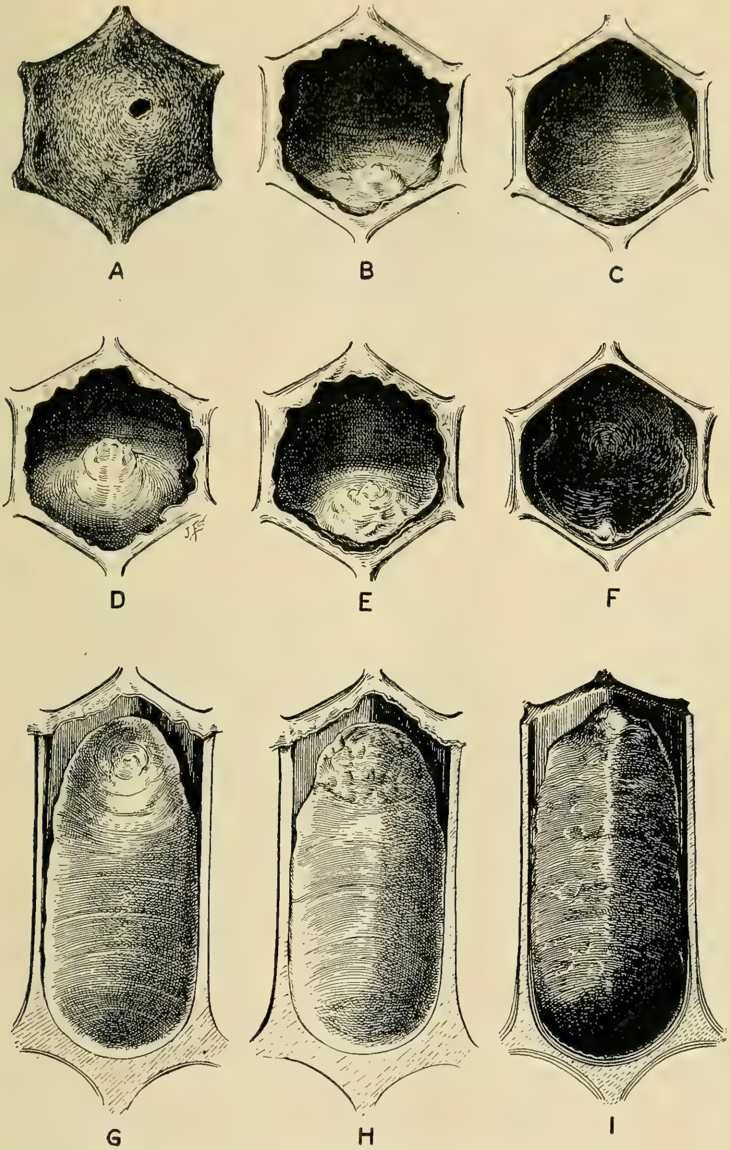

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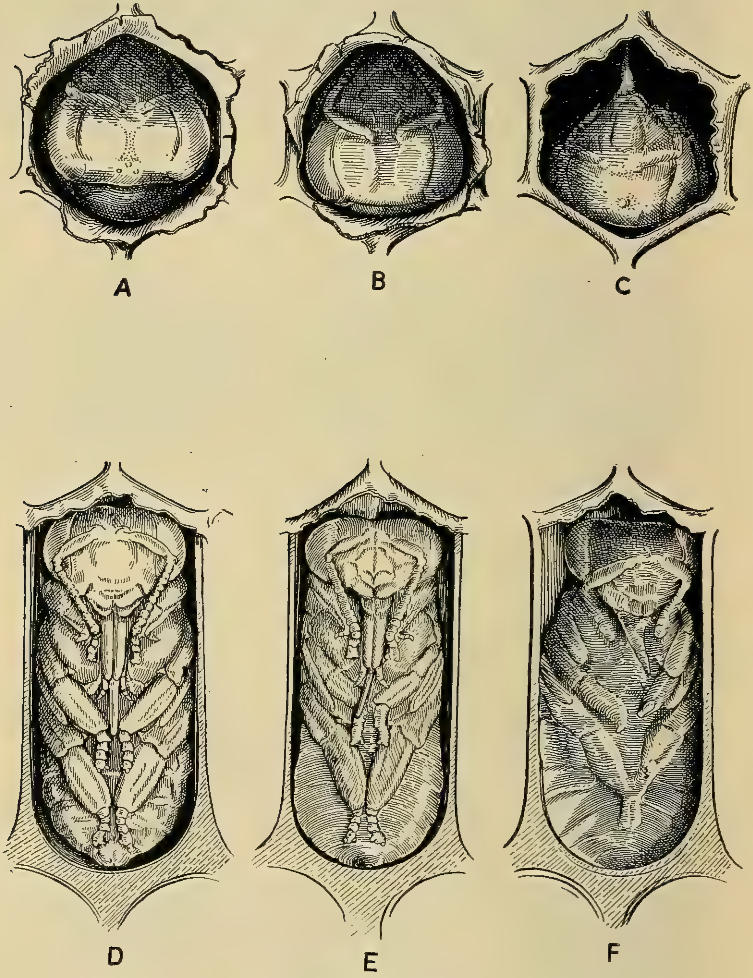

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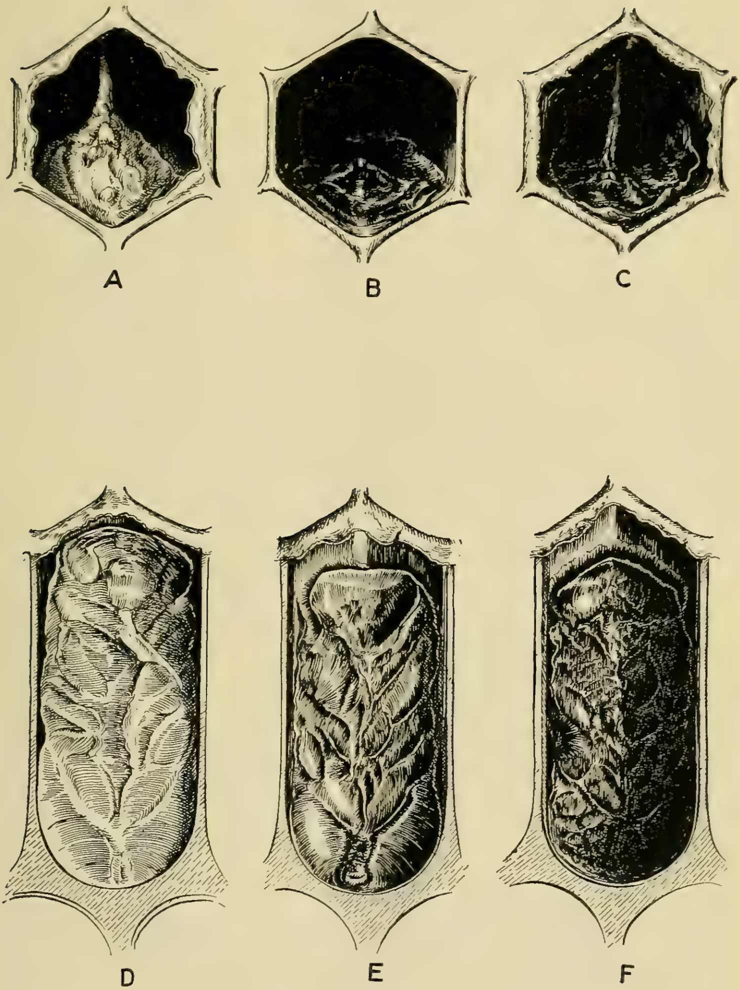

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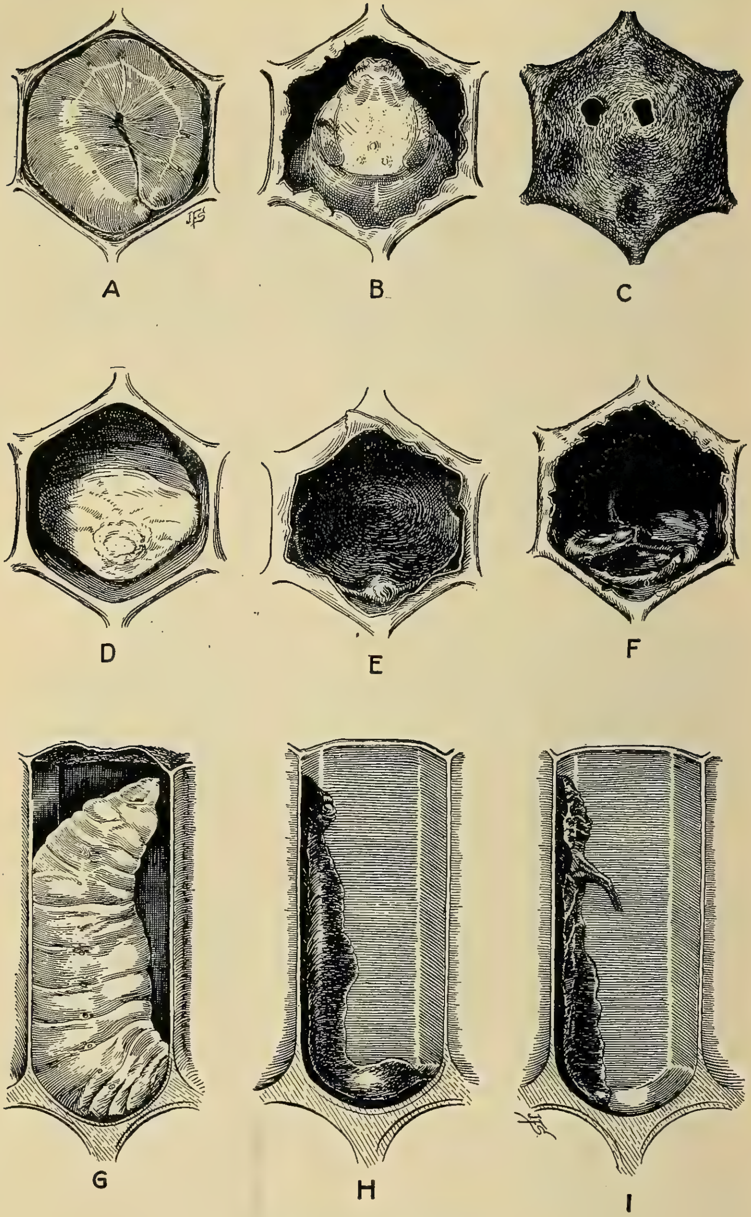

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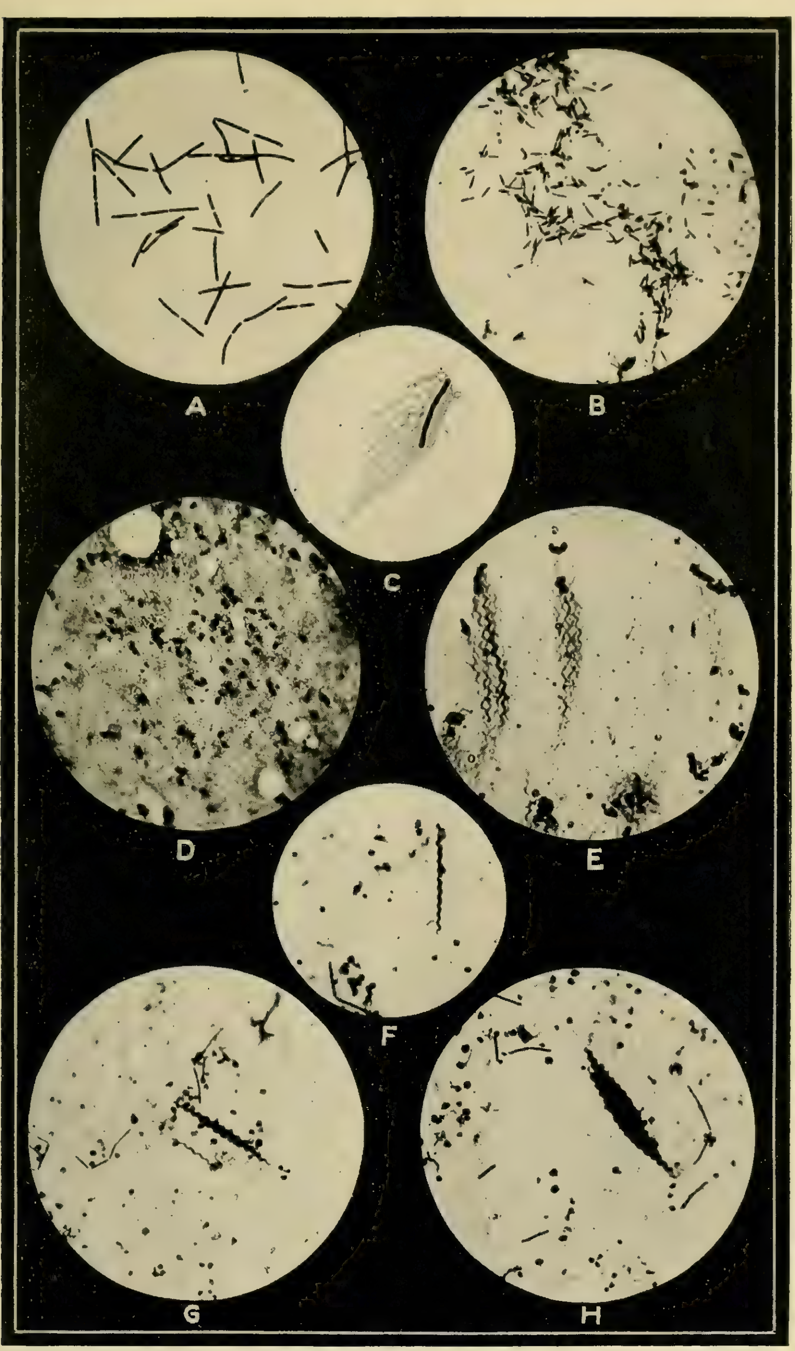

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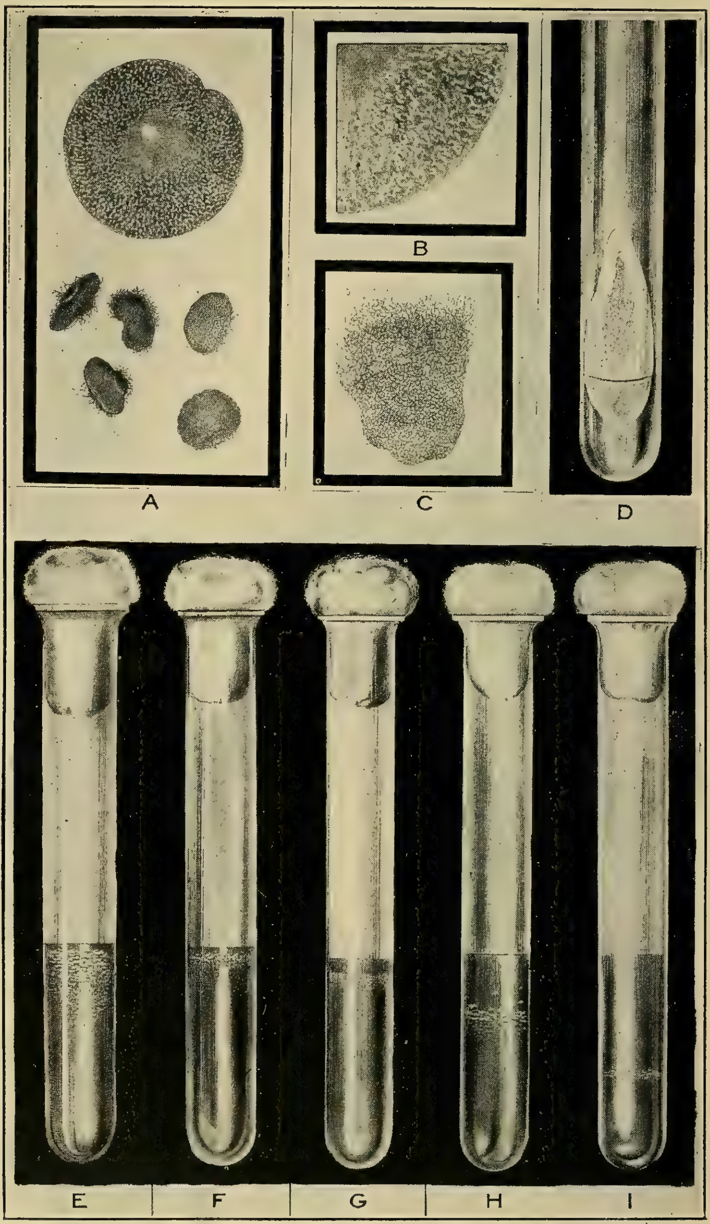

AMERICAN FOULBROOD.

UNITED STATES DEPARTMENT OF AGRICULTURE

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EUROPEAN FOULBROOD

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INTRODUCTION

European foulbrood is an infectious disease of the brood of bees caused by *Bacillus pluton*. It is characterized by the death of brood during its uncapped stage and by the absence of any marked odor. The disorder has a wide distribution and is fairly well known to beekeepers. The losses sustained by the infected apiary vary from a slight weakening of the colonies in some instances to the destruction of all of them in others.

Practical apiarists have determined much concerning the disorder while pursuing their profession. The writer in an earlier paper (15)[1] referred to the nature and extent of the progress that had been made in the study of the disease from the laboratory point of view. The present paper deals with results which have been obtained from a continuation of the work. Among the problems considered are: The resistance of *Bacillus pluton* to heat, drying, sunlight, fermentation, and disinfectants; the effect of the disease on the colony and on the apiary; and the transmission, diagnosis, and prognosis of the disease. Work directly on the treatment of the disease has not been attempted by the writer. Naturally, however, any treatment that is devised, if it is to be efficient and at the same time economical, must be based upon results obtained from the solution of such problems as those which have received attention in these studies.

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[1] Figures in parentheses refer to "Literature cited," p. 34.

Results obtained from a study of the disease in the laboratory and in the experimental apiary form the basis of the discussions contained in the present paper. Since the disease encountered in nature is very similar to the one produced by artificial inoculation, the importance of the studies is at once evident.

The paper [1] will be of interest, it is believed, not only to the apiarist who may wish to apply the facts here determined in the pursuit of his profession, but also to the investigator whose desire primarily is a further study of the disease.

NAME OF THE DISEASE

The term "foulbrood" was quite generally used in the past, as it still frequently is, for the two infectious diseases now known in America as European foulbrood and American foulbrood. In 1885 when Cheshire and Cheyne (4) in England made their studies on foulbrood and described *Bacillus alvei*, evidently they were not convinced that there were two distinct diseases that were being called by the one name foulbrood. The disease studied by them is the one which is the subject of discussion in the present paper. In the names for the two diseases it will be observed that the word "foulbrood" is retained in both instances. To this "European" is added for the disease on which early laboratory studies were made by these Europeans (Cheshire and Cheyne).

Dr. William R. Howard (6), of Texas, in 1900, worked for a brief period with this disease, reached the conclusion that it was a new one, and referred to it by the names "New York bee disease," or "black brood." Work by Moore and White (11) in 1902 showed that the disease was not new, but was the foulbrood studied by Cheshire and Cheyne (4). The names "New York bee disease," or "black brood," therefore, were superfluous, and as their use would have added to the confusion that already existed they were discarded. Beekeepers, entomologists, and pathologists, as a rule, are more or less familiar with the terms "foulbrood" and "*Bacillus alvei*." Usually, however, the ropy foulbrood—American foulbrood—is the one that is thought of, and the one that frequently has been associated in the literature with *Bacillus alvei.* This is unfortunate. While *B. alvei* is not the cause of any bee disease, it occurs very frequently with European foulbrood and is found only seldom in the ropy disease. In using the names European foulbrood and American foulbrood it is possible, however, to avoid confusion by bearing well in mind the history of the disease.

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[1] The present studies are similar to those made by the writer on sacbrood (17), Nosema-disease (18), and American foulbrood (19). A reference to these papers may be found helpful where the discussions in the present one are especially brief. The investigations were completed in September, 1916, and the paper was submitted for publication in October, 1918.

HEALTHY LARVÆ OF THE AGE AT WHICH THEY DIE OF EUROPEAN FOULBROOD

Bees dying of European foulbrood do so during the larval stage.[1] Death may take place at any time from the fourth day of larval life to pupation. For convenience of description the brood of the age at which death from European foulbrood occurs is placed here in three groups. Groups 1 and 2 include the uncapped and group 3 the capped larvæ.

GROUP 1

The youngest larva (Pl. II, D, G) that dies of European foulbrood practically covers the bottom of the cell. It lies either on its right or its left side, with its dorsal portion extending to the lateral walls of the cell. Its form is C shaped with the anterior and posterior extremities almost together. Its color is bluish white with a glistening surface, presenting a pearly appearance. The body is more or less opaque, due largely to the adipose tissue. Folds and furrows divide the surface into segments. In health these are quite prominent and the entire larva is turgid in appearance.

With the unaided eye spiracles and tracheæ can be seen with difficulty, but by slight magnification they are readily observed. Most of the tracheæ, appearing as white lines, extend either dorsally or ventrally on the lateral side of the larva, but a distinct chain connecting them will be observed to extend at right angles to these.

GROUP 2

Healthy larvæ (Pl. III, D, G) slightly older than those described in Group 1 constitute Group 2. The larva now completely fills the bottom of the cell. The dorsal side pressing against the lateral side walls of the cell causes the contour of the body to be in general hexagonal. The tracheæ are seen less easily than in younger larvæ, while the color, glistening appearance, prominence of segments, and turgidity are similar to those of the younger larvæ described in Group 1.

By turning the larva so that its dorsal surface may be brought into view (Pl. III, A) there is observed a more or less transparent narrow area along the dorsal median line extending nearly the length of the body. The contents of the stomach may be seen through this area. The color of the mass is due chiefly to the presence of pollen. It is usually some shade of yellow. The median area presents in its appearance a sharp contrast to the bluish-white, opaque portions on either side of it. Similar appearances are to be noted in the larvæ of Group 1.

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[1] The term larvæ as used in the present paper applies to the prepupæ as well as to earlier stages of the brood.

The larva removed from the cell performs only slight movements, lies partly coiled, and is more or less turgid. The segments are prominent. When the body wall is torn there flows from the ruptured wall the clear larval blood, in which are suspended often fat and other tissue cells which give to it a somewhat milky appearance. The stomach, a transparent tube easily torn into segments, contains a mass of partially digested food, pollen constituting usually a conspicuous portion of it.

GROUP 3

Group 3 consists of capped larvæ. These are, therefore, larger than those described in Groups 1 and 2. In the group are included the larvæ which have spun a cocoon as well as those which have not. An endwise position in the cell may or may not have been assumed. The larvæ are seen in various positions. Not infrequently some portion of the dorsal surface is turned toward the observer, the narrow, median, transparent area being in evidence as in younger larvæ. Healthy larvæ occupying an endwise position are described in papers on sacbrood and American foulbrood (17, 19) and will not be referred to further at this time.

SYMPTOMS

In European foulbrood, as in other brood diseases, the colony as a whole and not the individual bee should be considered as the unit in the discussion of the symptoms of the disease. The description of the symptoms recorded in the present paper is based chiefly upon observations made on the disease produced through artificial inoculations. In making the studies in the experimental apiary observations made by beekeepers have been duplicated and new facts determined. It has been possible also to locate errors which have been made in discussions of symptoms of the disease.

GENERAL SYMPTOMS FROM A CASUAL EXAMINATION

Death of brood during the feeding stage, in uncapped cells, is a characteristic of European foulbrood. The brood nest in the disease usually presents an irregular appearance, capped cells and uncapped ones being found scattered irregularly over the brood frames, giving to them the "pepper box" appearance (Pl. I) often referred to by beekeepers, a condition noticeable when the disease is fairly well advanced in the colony.

The dead larvæ lose their pearly whiteness and assume a yellowish color, later becoming brownish. This deepens often to a dark brown. The decaying remains are not characteristically ropy, as in American foulbrood. Marked viscidity is usually absent. When it is present the decaying mass can be drawn into threads but to a less extent than in the ropy disease. In advanced cases the disease may be accompanied by an odor, but in the writer's experience this never has been marked and never offensive.

As the disease in the colony advances, weakness becomes a symptom. In severe cases queenlessness may result from the infection. This, however, is by no means the rule.

SYMPTOMS MANIFESTED BY INDIVIDUAL LARVÆ SICK OR DEAD OF EUROPEAN FOULBROOD

Evidences of European foulbrood in the individual larvæ appear before and after death. The colony symptoms used most frequently in the diagnosis of the disease are largely post-mortem appearances of larvæ. Of much interest and frequently of considerable diagnostic value are the symptoms manifest by larvæ sick but not dead of the disease. For convenience in the description of the appearances of the sick or dead larvæ, the grouping used in describing the healthy larvæ (p. 3) is followed. The appearances of affected larvæ both living and dead are, of course, changing constantly. A description which is correct for one day or hour, it should be realized, is not likely to be entirely correct for the next.

GROUP 1

The youngest larvæ manifesting symptoms of European foulbrood are approximately 4 days old (Pl. II, A, B, C, E, F, H, I). In many cases at this stage of the disease a peristalsis-like movement of the body is marked and is readily observed by the unaided eye, but in others no such bodily movements are observed. The diseased larvæ at the time may be more transparent (Pl. II, B, H) than healthy ones of the same size. In such larvæ the tracheæ are quite prominent and more readily seen than in healthy ones. Occasionally numerous minute opaque areas are observed in these more transparent larvæ, giving to them a punctate appearance. Very often, however, this sign is not present. In many instances, indeed, no distinct symptom is observed until the larva approaches death. (Pl. II, A).

Larvæ (Pl. II, A, B, C, E, H, I) of this group dying or just dead of the disease lose their marked glistening appearance; their pearly whiteness gives way to a yellowish tint; the turgidity seen in healthy larvæ is diminished in the sick; and the folds and furrows indicating the segments of the body become less prominent. As the process of decay advances the yellowish hue changes, the color assuming a brownish tone. The segmental markings are less prominent, while the tracheæ often become quite distinct, appearing as white lines contrasted with the darker color of the larval remains (Pl. II, B). Not infrequently at this time there will be seen a chitinous envelope containing a watery-looking fluid in which is the larva proper (Pl. II, C; Pl. IV, A). The decay proceeds and the drying becomes evident. The larval mass settling upon the concave bottom of the cell causes the upper surface of the mass to be depressed about the center. At this stage the tracheæ not infrequently are seen distinctly in the drying mass. When the larval remains become dry they are known as the scale (Pl. II, F). The scales do not adhere closely to the cell and when removed are found to be thin and more or less circular in outline. They are convex and smooth on the side which was in contact with the bottom of the cell while the opposite surface—the one which, while in the cell, was toward the observer—is slightly roughened and concave.

GROUP 2

Larvæ (Pl. III) showing symptoms of European foulbrood and classed in this group have reached a sufficient size to fill the deepest third or more of the cell. The yellowish tint appears in contrast to the bluish white of the healthy larvæ (Pl. III, D, G). Increased movement may or may not be observed. Before and after death the remains may assume one of a number of positions in the cell. Not infrequently a portion of the dorsal surface is turned toward the observer (Pl. III, B). Usually through the transparent area along the median dorsal line a whitish or yellowish-white mass is to be observed. This mass is within the stomach of the larva and contains a large amount of bacterial growth (Pl. VIII, a, b, c) consisting very largely of *Bacillus pluton.* Often before death this mass is seen to move within the stomach in response to the peristalsis-like movements of the body of the larva.

At the time of death the larva usually occupies some unnatural position, being more or less curled up and lying upon the floor of the cell (Pl. III, C, E, F, H, I). Lessened turgidity, a relative dullness of the surface appearance, and a yellowish tint are present. Not infrequently the two ends of the larva are directed more or less toward the bottom of the cell and some portion of the dorsal surface is toward the opening of it (Pl. III, E, H, I). Among the dead larvæ will be found some with one end directed toward the bottom, and the other toward the mouth of the cell, the body occupying a more or less spiral position against the side walls and floor of the cell (Pl. III, F).

Later the dead larval remains assume a brownish tint which deepens to varying shades as decay continues and drying takes place. During the early part of the decay, the firmness of the body wall permits the removal of the larva intact from the cell. Later, however, it offers but little resistance and is easily ruptured. The decaying mass before drying often attains a certain amount of viscidity. Sometimes it is of a doughy consistency, at other times it is purulent or sputumlike, while at times it assumes a viscidity that will permit of its being drawn out to the extent of an inch or more. When the larval mass becomes dry it forms an irregular scale, usually brown in color, lying on the floor or side wall of the cell or both, but not adhering closely to them.

GROUP 3

A larva dying of European foulbrood after being capped may be found occupying one of many positions within the cell (Pl. IV, C, D, E; Pl. V, D, E, F, G, H). Dying before the two-day quiescent period that precedes pupation, the remains during decay and as a scale resemble in many respects those of larvæ described in group 2. The dry scales occupy usually an irregular position on the floor of the cell (Pl. IV, F, G). Dying during the two-day quiescent period, however, the scales (Pl. V, F, I) resemble very much those of larvæ dying at the same age of American foulbrood. The larval mass assumes the brownish hue which deepens as the decay advances, reaching a dark brown. Viscidity is present in the decaying larval mass, but the extent to which the decaying material may be drawn out is less than in American foulbrood. The scale is less brittle and more rubberlike.

At no time has the writer observed pupæ dead of European foulbrood. If they die of the disease it is a rare occurrence.

The removal of larvæ sick or dead of the disease is accomplished to a greater or less degree by adult workers. The larvæ are either partially or entirely removed. This is usually done piecemeal. In an infected colony will be found, therefore, the remains of larvæ of different ages (Pl. IV, B) and (Pl. V, A) in varying numbers.

ETIOLOGY

PREDISPOSING CAUSES

Age.—Infection in European foulbrood takes place during the feeding stage and at some time after the first day of larval life, the larvæ being more often 2 days of age, or older. Death takes place somewhat more than 2 days from the time of infection. As a rule, therefore, a larva has passed its fourth day of larval life before death from European foulbrood occurs. From this age to pupation larvæ may die of the disease. The writer has not encountered death among brood which has reached the pupal stage. Adult bees are not susceptible to infection.

Sex.—Worker, drone, and queen larvæ are all susceptible to infection with *Bacillus pluton* and any of these may die of European foulbrood.

Race.—Complete immunity from European foulbrood has not been found among the races of bees studied. Experimental work recorded in the present paper involved the use of at least five colonies of "tested Italians," two of "tested Carniolans," and two of "tested Caucasians." For the most part the bees used were "untested Italians," but among the colonies were a few common blacks. In all these strains the disease was readily produced through experimental inoculation. The examination of numerous samples of diseased brood received from beekeepers throughout the United States suggests that all races commonly kept by American beekepeers are susceptible to European foulbrood. The relative immunity of the different races has not been demonstrated by the studies. These facts, however, do not dispute the observation by practical beekeepers that some strains of bees show a greater colony resistance than others.

Climate.—From reports of studies made in Austria by Muck (12), in Denmark by Bahr (1), in England by Cheshire and Cheyne (4), in Germany by Zander (20), and in Switzerland by Burri (3), it is clearly evident that the disease discussed in the present paper occurs in these different countries. It has been encountered also in many sections of the United States and Canada. This distribution shows that the infection can exist under a variety of climatic conditions. The practical import of the fact is that the presence of European foulbrood in any locality can not be attributed entirely to the climate of the region.

Season.—Beekeepers have observed that European foulbrood occurs with greatest severity before midsummer rather than later in the season. The disease, it has been shown experimentally, can be produced, however, at any season of the year at which brood is being reared. Its severity at any given season is to be attributed, therefore, to environmental conditions rather than to the difference in the susceptibility of larvæ during the different seasons.

Food.—As in American foulbrood it is found that the cause of the disease in the colony is governed very little if at all by the quality of food gathered by bees. Indirectly, however, the quantity present in the hive or obtainable often does influence its course materially.

EXCITING CAUSE

That *Bacillus alvei* may be present in large numbers in brood dead of foulbrood was demonstrated by Cheshire and Cheyne (4) in 1885.

For a decade and a half following the observation the belief was quite general that this bacterium was the exciting cause of a bee disease. The view was then seriously challenged. In 1906 the only positive conclusion in regard to the relation between European foulbrood and *Bacillus alvei* that could be drawn by the writer (13) was that this species occurs in brood dead of the disease.

William R. Howard (6), of Texas, after a brief study of the disease reported in 1900 the presence of an organism which he called *Bacillus millii*. He cultivated the species apparently with ease. In 1904 Bahr (1) in Denmark found a small oval bacterium in a brood disease in which larvæ dying in uncapped cells are yellowish in color and not ropy in consistency. Burri (3) in 1906 encountered in his studies on the brood diseases a small bacterium which he referred to as *guntheri*-forms. The species was cultured and compared with *Bacterium guntheri* and found to be somewhat different. In 1907 Maassen (7) obtained from brood material cultures of a species which he named *Streptococcus apis*. White (14) in 1908 reported the presence of a small organism in European foulbrood which had refused to grow on artificial media. The species was not the one, therefore, with which the investigators just referred to had worked. That this organism might be the exciting cause of the disease was noted. Pending more information regarding it, the species was not given a name but was referred to as bacillus "Y." That this species bears a direct etiological relation to the disease was demonstrated in 1912 by the writer (15) and the name *Bacillus pluton* was then given to it.

As the cultivation of *Bacillus pluton* on artificial media had not been accomplished the conclusion that it is the exciting cause of European foulbrood was arrived at by eliminating all other possible agencies. The observations furnishing the proof appear in an earlier paper (15). By demonstrating *Bacillus pluton* to be the cause of the disease, *Bacillus alvei*, *Streptococcus apis*, *Bacterium eurydice*, and *Bacillus orpheus*, and still other species occasionally encountered, were thereby proven to be secondary invaders.

To eliminate the possibility of a filterable virus in European foulbrood 10 colonies were inoculated with filtrates obtained from aqueous suspensions of brood sick and dead of the disease. In six instances the Berkefeld N filter was used and in four the Pasteur-Chamberland F was employed. In no case was the disease produced. Studies recorded in the present paper on the resistance of *Bacillus pluton* to heating, drying, fermentation, and disinfectants show that when the virus of the disease is not destroyed this species is still alive. This fact is further evidence in support of the conclusion that the species *Bacillus pluton* is the virus of the disease.

BACILLUS PLUTON

An artificial medium for the cultivation of *Bacillus pluton* has not yet been devised. To accomplish this may or may not be a particularly difficult task. The media ordinarily used in the laboratory are not suitable. Bee-larvæ agar, brood-filtrate media, egg-yolk-suspension agar (19), and combinations of these have not thus far proved sufficient for the purpose. The species is an unusual one. The generic classification has not been determined definitely and this may not be possible until the proper condition for the artificial cultivation of the species has been supplied.

The morphology of *Bacillus pluton* is somewhat variable. In very early infection its form is that of a short rod in pairs or in chains, or possibly of a coccus with the individuals similarly arranged (fig. 1; Pl. VII, B). The length is then equal to or somewhat greater than the breadth. In slightly later stages of infection the predominating form is that of a lancet-shaped coccus (fig. 1; Pl. VII, A), and in late stages this form is present almost exclusively. The lancet form occurs singly, varying greatly in size and having a length which approximates twice the width. The length is more often less than 1 µ than greater. The organism colors uniformly with the aniline stains, stains with iron hematoxylin, and is gram-positive. It does not form spores. This is evidenced by the microscopic appearance and also by the thermal death point of the species. Its resistance to drying, disinfectants, and other environments is discussed later in the present paper.

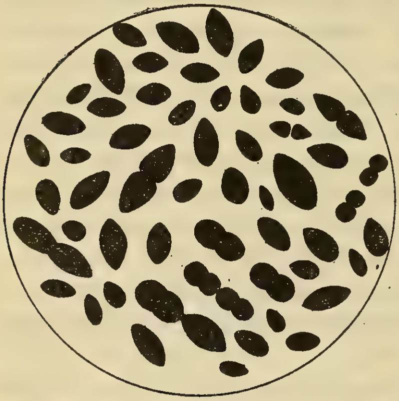

FIG. 1.—*Bacillus pluton.*

Seven rabbits inoculated, six subcutaneously and one intraperitoneally, with a suspension of larvæ dead of European foulbrood proved to be refractory. Only a slight rise of temperature followed the inoculations and the weight was not materially affected. Six guinea pigs inoculated subcutaneously with similar material proved not to be susceptible to infection with the species. Four pigeons inoculated in the pectoral muscles and two white rats inoculated subcutaneously also proved refractory. In none of these inoculated animals were there any lesions of particular note produced.

Growth of *Bacillus pluton* in the infected larva begins close to the surface of the peritrophic membrane (Pl. VII, I) in contact with the food of the larva. As growth continues the bacterial mass extends toward the center of the lumen of the peritrophic sac (Pl. VII, K), finally filling it more or less completely (Pl. VII, J). The growth does not always take place uniformly along the peritrophic membrane (Pl. VII, J), nor does it extend beyond it (Pl. VII, I, J, K), but is inclosed within the sac, the tissues of the larvæ not being reached. The multiplication of the organism after the death of the host, if, indeed, it takes place at all, is limited.

Secondary invaders, chiefly *Bacillus alvei*, *Bacterium eurydice*, *Streptococcus apis*, and occasionally *Bacillus orpheus*, and a few others, are encountered at various stages of the disease and during the decay of the larva. During the life of the larva these species also remain within the peritrophic sac.

BACILLUS ALVEI

Bacillus alvei (fig. 2; Pl. VII, D, F) is present very frequently and in very large numbers in larvæ dead of European foulbrood. The species was well described by Cheyne (4). Descriptions may be found elsewhere also (11, 13). It is readily recognized and may be differentiated easily from other spore-producing species occasionally encountered in the diseased brood.

Bacillus alvei is not the active cause of any bee disease. It seems probable, however, that it plays a rôle in European foulbrood, but the extent is not fully known. The species is present usually, if not invariably, in large numbers in the rubberlike scales (Pl. V, F, I), which resemble so much those of American foulbrood. The decayed larval mass, which forms the scale, before becoming dry is ropy in consistency similar to that of American foulbrood but to a less degree. It seems probable that this ropiness is due more or less directly to *Bacillus alvei*. On account of this viscidity the decaying mass, as well as the scales, are removed with greater difficulty than are most larvæ dead of European foulbrood. The result, as often observed, is that these brown viscid decaying larvæ or the rubberlike scales resulting from them are the only evidence that European foulbrood is present in the colony.

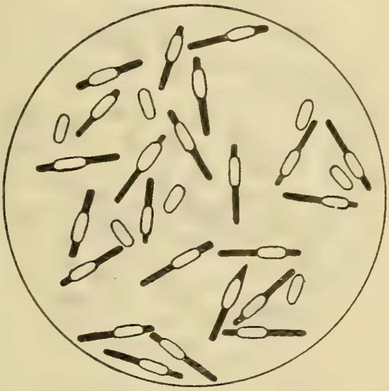
FIG. 2.—*Bacillus alvei.* Spores free from and others within rods.

While *Bacillus pluton* in such larval masses and scales is often difficult to detect microscopically, its presence can be demonstrated through the experimental inoculation of healthy larvæ. Inasmuch as *Bacillus pluton* will live for a considerable period in the scales, it seems quite probable that the disease might in some cases be carried over for months or even over winter through the medium of these rubberlike scales.

It is of interest to know that the amount of disease resulting immediately from inoculations in which scale material is used is much less than when larvæ recently dead of the disease are used. This is true also of dead larvæ stored in Petri dishes compared with smears allowed to dry immediately from larvæ recently dead of the disease. These facts indicate a possible deleterious effect on *Bacillus pluton* of the secondary invaders multiplying in the decaying larvæ.

STREPTOCOCCUS APIS

It is most probable that *Streptococcus apis* is the species that was isolated from diseased brood by Burri (3) and referred to by him in 1906 as "*güntheri*-forms." Maassen described it in 1908 (8). The organism grows well at incubator, room, and refrigerator temperatures in most of the media ordinarily used in the laboratory. Its cultural characteristics suggest the micrococci rather than the streptococci. Confusion in some of the earlier investigations was due evidently to the resemblance of *Streptococcus apis* and *Bacillus pluton* morphologically. To this fact is due the chief interest in the species *Streptococcus apis*. When encountered in larvæ dead of European foulbrood it can be identified readily by culturing. The generic position of this species should be considered as being not altogether certain.

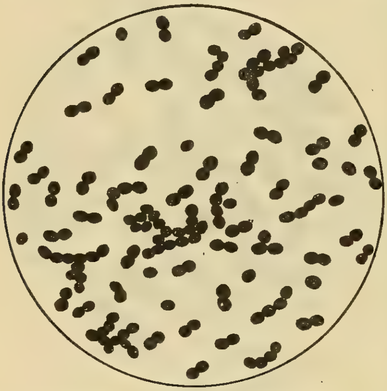

FIG. 3.—*Streptococcus apis.*

Occurrence.—*Streptococcus apis* is occasionally encountered in larvæ dead of European foulbrood and often is present in large numbers.

Morphology.—It is more or less spherical (fig. 3; Pl. VII, E), occurring singly and in pairs with occasionally a chain of 2 or more pairs when grown in liquid media. In larval remains not infrequently the ends may be somewhat pointed.

Staining properties.—It colors uniformly and readily with the common stains, and retains the stain after Gram's method.

Glucose agar plate.—Within a day growth is visible. Colonies never become large. Surface colonies are usually less than 2 mm. They are circular with uniform outline and a well-defined border, are grayish by reflected and bluish by transmitted light, are smooth and convex, are moist and glistening in appearance, and are friable in consistency. When magnified the surface colonies appear light brown in color, and granular in structure, the density decreasing from the center to the periphery. Deep colonies appear dense, dark brown, and coarsely granular. They are in general lenticular to oval but are sometimes almost spherical in form.

Glucose gelatin plate.—At refrigerator temperature and within 3 days, the surface colonies begin to liquefy the gelatin, each liquefied area appearing somewhat as a minute drop of water.

Agar slant.—In one day numerous gray colonies cover the inoculated surface.

Bouillon.—Within a day the medium is uniformly and moderately clouded.

Fermentation.—In glucose, lactose, saccharose, levulose, maltose, and mannite bouillons, a uniform clouding of the media occurs. The growth takes place in both arms of the tube, but is heavier in the open one. Considerable acidity, but no gas, is produced.

Milk.—Milk is rapidly coagulated. Digestion of the coagulum follows. In from 3 to 5 days more than one-half has been changed. Within 24 hours the color is discharged in litmus milk, except at the top of the medium. In other respects it is like the plain milk.

Potato.—No visible growth. That growth in the potato water takes place is confirmed by microscopic examination.

Gelatin stab.—Liquefaction along the line of puncture is appreciable after one day. In four days a cylinder of liquefied gelatin 1 cm. in diameter surrounds the original line of puncture and soon extends to the walls of the tube.

Pathogenesis.—No disease results when the brood of bees is fed cultures of *Streptococcus apis* either by the direct or indirect method. A rabbit and two guinea pigs inoculated with a pure culture of *Streptococcus apis* were not susceptible to infection with the species.

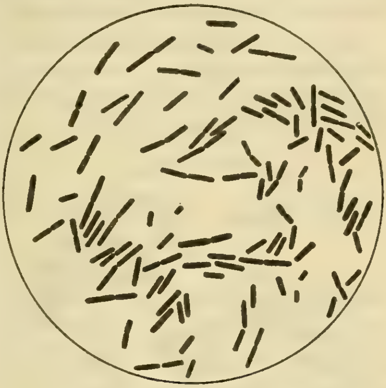

FIG. 4.—*Bacterium eurydice.*

BACTERIUM EURYDICE

The presence of this species in European foulbrood was pointed out by the writer in an earlier publication (15). Among the secondary invaders in larvæ infected with *Bacillus pluton*, *Bacterium eurydice* is one of the earliest to be found. It is often present in considerable numbers. In plating for the species the stomach contents from larvæ sick, but not dead, of the disease should be used. In studying this species cultures were isolated which in some respects differed from it. Whether these are different species or belong to a group of which *Bacterium eurydice* is a representative has not been definitely determined.

To isolate *Bacterium eurydice* the plating has been done with glucose agar. Incubation must be carried out at room temperature. Growth of the species is always slow and never luxuriant. Under favorable conditions colonies are visible after one day. To preserve cultures they must be renewed frequently.

Occurrence.—*Bacterium eurydice* is frequently present in larvæ sick or recently dead of European foulbrood.

Glucose agar plate.—To the naked eye the surface colonies are slightly convex, smooth, and glistening. They are from 1 to 2 mm. in diameter, circular and uniform in outline. The color is bluish by transmitted and grayish by reflected light. Under a two-thirds objective they are a light brown, and are finely granular near the periphery, but more coarsely granular near the center.

Morphology.—The rod (fig. 4; Pl. VII, C) is small and slender with slightly rounded ends, occurring usually in pairs or singly. It is nonmotile and no spores are produced.

Staining properties.—It is stained easily and uniformly with the ordinary aniline stains and is Gram-negative.

Oxygen requrements—Growth is better in the presence of air than in anaerobic conditions.

Bouillon.—Growth takes place slowly, producing a uniform cloudiness with no pellicle. After a week or more a somewhat viscid sediment is present.

Sugars.—Growth in the sugar media is slow, variable, and never luxuriant. Both arms may be clouded. Glucose or levulose when added improves a medium. Fermentation with gas does not take place in any of the sugars. A noticeable amount of acid is formed when glucose and levulose are used, the other sugars being less affected. A 1 per cent honey solution supports a moderate growth. Brood filtrate as a rule improves media.

Milk.—In plain and litmus milk no changes are visible.

Potato.—Growth on potato is slow. When present, the culture is for the most part grayish in color.

Gelatin stab.—A bluish gray growth appears slowly along the line of inoculation. No liquefaction follows.

Pathogenesis.—No ill results are observed when cultures of *Bacterium eurydice* are fed to healthy colonies of bees. A rabbit inoculated subcutaneously with a pure culture proved to be refractory.

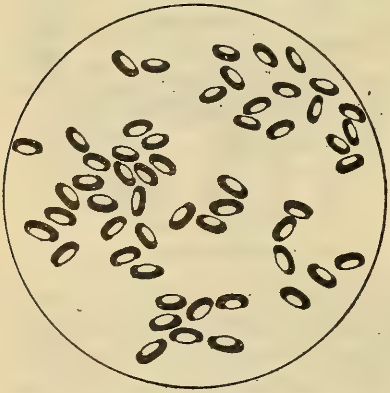

FIG. 5.—*Bacillus orpheus:* Spore formation.

BACILLUS ORPHEUS

The name *Bacillus orpheus* was given to an interesting species occasionally encountered in European foulbrood (15). In one instance the species was found very widely distributed in an apiary in which heavy losses were being sustained from the disease. In this case the dead larvæ when dry were stonelike in character, the petrified remains breaking like so much marble. Usually the species is met with in a less number of the affected larvæ. It can be readily identified from its morphology and cultural characteristics. A description of the species has been made by McCray (9). An organism similar to *B. orpheus* in many respects has been described by Laubach (5) and named *Bacillus laterosporus.*

The organism is a motile spore-bearing rod with a few peritrichic flagella. Spore formation begins in a few hours on the surface of the agar at incubator temperature, the rod swelling toward the center and becoming fusiform. Soon, as determined from stained preparations, the spore is seen occupying one side of the rod with the protoplasm distributed along the opposite side and the two ends (fig. 5; Pl. VII, H). The rod, together with the spore within it, measures about 2.4μ in length and 1.2μ in width. This relation of spore and rod persists in cultures on a solid medium for a long period, especially at room temperature. Good growth, no gas, and only slight changes in reaction occur in the sugar media. A slight coagulum forms in the milk which is slowly digested. Gelatin is rapidly fluidified.

Bacillus orpheus is not pathogenic for the brood of bees when inoculated by feeding either by the direct or indirect method. Silkworm larvæ succumb following inoculation by feeding and also by puncture.

TECHNIQUE[1]

Artificial conditions for the successful cultivation of *Bacillus pluton* have not yet been obtained. That this can be achieved by further study is not at all improbable. Without having accomplished this, it has been possible, however, to make the studies on the biology of the parasite that were most desired. This was done through experimental work, using the larvæ of bees. The inoculations were made by feeding a suspension of the organism in sugar sirup.

Two methods were employed in making the feedings, which will be referred to here as (*a*) the indirect method, in which the colony is inoculated, and (*b*) the direct method, in which only a few larvæ are inoculated. Cane sugar and water were used in preparing the sirup in the proportion approximately of 3 to 2. This solution was then brought to the boiling point.

From 5 to 10 diseased larvæ furnish sufficient infective material when the indirect method is followed. These, after being picked from the brood frame, are thoroughly crushed, added to about 300 c. c. of the cooled sirup, and fed to a colony.[2] When the suspension contains the living virus, symptoms of European foulbrood appear in 3 days following the inoculation. The earliest evidence of disease is manifested by sick rather than dead larvæ (p. 5). Often fragments of larvæ (Pl. IV, B) are found upon examination of the brood nest.

In the direct method *Bacillus pluton* is taken from the stomachs of infected bees. Sick rather than dead larvæ are preferred for obtaining the virus free from the body tissues. By the use of dissecting needles and with a little care the stomach contents (Pl. VIII) can be pulled out of the blind end of the organ (15). The virus-containing material thus obtained is triturated with water and the aqueous suspension is added to sirup. The suspension of *Bacillus pluton* in a thin sirup is used in making the inoculation. Larvæ about 2 days old are especially desirable for the direct method. The inoculation is made by adding a small amount of the suspension to the food of the larvæ by means of a capillary pipette made from glass tubing of small bore. Care must be exercised in thus feeding the larvæ. Too much of the suspension will often float the larva. There is danger also that it will be changed in position mechanically by means of the feeding pipette. In either event the chances are that such larvæ will be removed subsequently by the bees. Considerable larval food already in the cell is advantageous. This method has proved to be especially useful in much of the experimental work recorded in the present paper. It has the advantage of being both economical as to the number of colonies needed, and definite. During the third day following the hour of inoculation symptoms of European foulbrood will be observed if infection is produced. By the fourth day frequently all of the infected larvæ will have been removed by the bees. Symptoms of European foulbrood infection manifested by larvæ sick rather than dead have proved to be especially useful for experimental purposes in these studies.

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[1] The technique in general which was found to be satisfactory for bee-disease studies is detailed to some extent in the sacbrood paper (17).

[2] The experimental colony is described in earlier papers (17, 18).

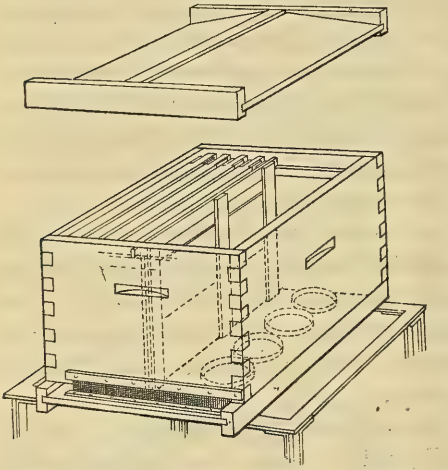

FIG. 6.—Experimental hive, having 4 Hoffman frames, a division board, Petri dishes as feeders, the entrance nearly closed with wire cloth, and the opening on the side of the hive body occupied by the frames. (Author's illustration.)

During most of the time that experimental studies are being made it is necessary to have fresh diseased material at hand. A supply can be maintained by using one or more colonies for this purpose. Repeated inoculations of the colony usually must be made at intervals of a few days or after longer periods, depending on its condition and the need for the virus. The indirect method is especially indicated in inoculating these colonies.

Frequently colonies which have been employed in European foulbrood experiments can be used again for further experiments on the disease. This must be done with some care, however. The condition of the brood always should be noted before an inoculation is made. European foulbrood colonies serve very well the purpose of experimental colonies for the other brood diseases and for Nosema-disease. In fact, not infrequently during these studies experiments on two or more of the diseases were in progress in a colony at the same time.

The apiary (Pl. VI) used in the experimental work with European foulbrood was the same as the one employed in the study of sacbrood (17), Nosema-disease (18), and American foulbrood (19). The hive (fig. 6) and the experimental colonies, where they were not the same, were similar to those used in the other studies. The method of making the inoculations was also similar. The colonies were, therefore, in the open and the bees had free access of flight. The same precautions taken to minimize robbing, swarming, absconding, and drifting of bees were observed in the experiments with this disease as with the other diseases. All hives which had housed European foulbrood colonies were flamed before they were used again to be certain that there would be no infection from such a source. Whether the queens used had been in diseased colonies need not give one any concern. Further reference to the technique followed in the present studies will be made as the experiments are discussed.

THERMAL DEATH POINT OF BACILLUS PLUTON

The result of the experiments recorded by the writer in an earlier paper (16) shows that when suspended in water the thermal death point of *Bacillus pluton* is approximately 63° C., the period of application being 10 minutes. Further experiments have been conducted in which the organism was suspended in honey and heated. After being heated, healthy larvæ are inoculated by feeding, using the direct or pipette method. Table I summarizes the experiments made:

TABLE I.—*Resistance to heat of Bacillus pluton suspended in honey*

Date of inoculation.	Temperature.		Period of heating.	Results of inoculation.
1915.	*°C.*	*°F.*	*Minutes.*	
June 15	67	153	10	European foulbrood produced.
Do	70	158	10	Do.
Do	75	167	10	Do.
June 22	76	169	10	Do.
Do	78	172	10	Do.
Sept. 22	79	174	10	No disease produced.
June 15	80	176	10	Do.
June 18	80	176	10	Do.
Sept. 27	81	178	10	Do.
June 19	85	185	10	Do.
Do	90	194	10	Do.

The results given in the foregoing table show that the thermal death point of *Bacillus pluton* suspended in honey is approximately 79° C., maintained for 10 minutes.

RESISTANCE OF BACILLUS PLUTON TO DRYING

In conducting experiments relative to the effect of drying on *Bacillus pluton* the stomach contents (Pl. VIII) of larvæ sick or recently dead of European foulbrood are spread in a thin layer in Petri dishes or on slides. From time to time after the films are made healthy larvæ are inoculated by feeding a suspension of the drying larval material suspended in a weak sirup solution. When no infection results the germ is considered as having been destroyed. Observations have been made on the virus kept at incubator, room, outdoor, and refrigerator temperatures and shielded from the light in each instance. The experiments conducted with *Bacillus pluton* in these environments are summarized in Tables II, III, IV, and V which follow:

TABLE II.—*Resistance of Bacillus pluton to drying at incubator temperature*

Date of inoculation.	Period of exposure.		Results of inoculation.
	Months.	*Days.*	
1914.			
July 3		10	European foulbrood produced.
July 10		17	Do.
July 17		24	Do.
July 25	1	2	Do.
Aug. 3	1	7	Do.
Aug. 15	1	17	Do.
Sept. 1	2	0	Do.
Sept. 16	2	11	Do.
Sept. 29	3	0	Do.
1915.			
June 29	9	10	Do.
July 13	12	2	Do.
July 9	12	0	No disease produced.
Sept. 20	14	18	Do.
Sept. 17	14	20	Do.
1916.			
Sept. 8	24	0	Do.

TABLE III.—*Resistance of Bacillus pluton to drying at room temperature*

Date of inoculation.	Period of drying.		Results of inoculation.
	Months.	*Days.*	
July 25, 1914	1	1	European foulbrood produced.
Sept. 16, 1914	1	21	Do.
Sept. 1, 1914	2	8	Do.
Sept. 28, 1914	2	21	Do.
Sept. 29, 1914	3	0	Do.
Oct. 6, 1914	3	14	Do.
Jan. 29, 1915	9	10	Do.
July 9, 1915	12	6	Do.
Aug. 3, 1914	11	13	No disease produced.
June 22, 1915	11	15	Do.
June 25, 1915	11	18	Do.
Aug. 9, 1915	12	2	Do.
Sept. 17, 1915	14	10	Do.
Sept. 20, 1915	14	18	Do.
Sept. 8, 1916	24	0	Do.
Do	36	0	Do.

TABLE IV.—*Resistance of Bacillus pluton to drying at outdoor temperature*

Date of inoculation.	Period of drying.		Results of inoculation.
	Months.	*Days.*	
Sept. 2, 1914		33	European foulbrood produced.
Sept. 16, 1914		47	Do.
Oct. 13, 1914		74	Do.
May 26, 1915	9	21	Do.
June 19, 1915	10	18	Do.
May 17, 1915	13	17	Do.
Aug. 3, 1915	12	3	No disease produced.
Aug. 17, 1915	12	17	Do.
June 23, 1916	23		Do.

TABLE V.—*Resistance of Bacillus pluton to drying at refrigerator temperature*

Date of inoculation.	Period of drying.		Results of inoculation.
	Months.	*Days.*	
Oct. 17, 1915	....	26	European foulbrood produced.
Sept. 18, 1916	3	28	Do.
May 3, 1916	6	12	Do.
June 23, 1916	8	0	Do.
May 26, 1916	8	2	Do.
June 23, 1916	9	0	Do.
July 31, 1916	10	7	Do.
Sept. 18, 1916	10	18	Do.

From Table II it will be observed that *Bacillus pluton* in a dry film made from the contents of infected larvæ resisted drying at incubator temperature for approximately one year. Table III shows that at room temperature, other conditions being similar, the resistance is approximately equal to that at incubator temperature. At outdoor temperature, as shown by Table IV, the resistance is again approximately the same. At refrigerator temperature, Table V, the experiments do not include the period at which *Bacillus pluton* is destroyed. In 10 months the organism was still viable and the results of the inoculations indicate from the character of the infection produced after such a period that at refrigerator temperature *Bacillus pluton* will remain alive for a longer period than at the other temperatures studied.

RESISTANCE OF BACILLUS PLUTON WHEN DRY TO DIRECT SUNLIGHT

In experiments relative to the resistance of *Bacillus pluton*, when dry, to the direct rays of the sun, smears are made of the contents of stomachs of European foulbrood larvæ in Petri dishes or on slides, and after becoming dry are exposed to the direct rays of the sun. After intervals reckoned in hours inoculations are made by feeding, using the direct method. Infection resulting from such inoculations shows that the drying has not killed the organism. In Table VI experiments performed in this connection are summarized:

TABLE VI.—*Results of inoculation with Bacillus pluton in a dry film exposed to direct sunlight*

Date of inoculations.	Period of exposure.	Results of inoculations.
	Hours.	
July 21, 1914	3	European foulbrood produced.
Sept. 18, 1913	6	Do.
July 31, 1914	7	Do.
Sept. 22, 1915	8	Do.
July 21, 1914	10	Do.
Sept. 27, 1915	14	Do.
Aug. 7, 1914	15	Do.
July 21, 1914	16	Do.
Aug. 7, 1914	20	Do.
Sept. 10, 1915	20	Do.
Sept. 25, 1915	21	Do.
July 22, 1914	23	Do.
Sept. 8, 1915	27	Do.

TABLE VI.—*Results of inoculation with Bacillus pluton, etc.*—Continued

Date of inoculations.	Period of exposure.	Results of inoculation.
	Hours.	
Sept. 20, 1915	21	No disease produced.
Sept. 24, 1915	23	Do.
Sept. 14, 1915	24	Do.
Aug. 16, 1915	26	Do.
Sept. 14, 1915	26	Do.
Sept. 13, 1915	31	Do.
Sept. 20, 1915	38	Do.
Aug. 3, 1915	40	Do.
Sept. 14, 1915	44	Do.
Aug. 16, 1915	46	Do.
Aug. 23, 1915	63	Do.
Sept. 14, 1915	95	Do.

Observations recorded in Table VI show that *Bacillus pluton* in a dry film made from the contents of the stomachs of larvæ sick or recently dead of European foulbrood resists the direct rays of the sun for from 21 to 31 hours.

RESISTANCE OF BACILLUS PLUTON IN WATER TO DIRECT SUNLIGHT

In performing the experiments relative to the effect of direct sunlight on *Bacillus pluton* suspended in water, an aqueous suspension of the contents of stomachs of infected larvæ is exposed, in a Petri dish with the top removed, to the direct rays of the sun. After intervals reckoned in hours inoculations of healthy larvæ are made to determine whether the organism is viable. The direct method is used. Experiments made in this connection are summarized in Table VII:

TABLE VII.—*Resistance of Bacillus pluton suspended in water exposed to the direct rays of the sun*

Date of inoculation.	Period of exposure.	Results of inoculation.
1915.	*Hours.*	
Aug. 24	1	European foulbrood produced.
Do	2	Do.
Aug. 16	2	Do.
Aug. 8	3	Do.
Aug. 9	3	Do.
Aug. 16	3	Do.
Aug. 24	3	Do.
Sept. 13	4	Do.
Aug. 18	5	Do.
Aug. 16	5	No disease produced.
Sept. 14	5	Do.
Aug. 17	6	Do.
Aug. 20	7	Do.
Sept. 14	7	Do.
Do	8	Do.
Do	9	Do.
July 28	10	Do.
Aug. 20	18	Do.

Table VII shows that *Bacillus pluton*, when suspended in water and exposed to the direct rays of the sun, was destroyed in from 5 to 6 hours.

RESISTANCE OF BACILLUS PLUTON IN HONEY TO DIRECT SUNLIGHT

Experiments were made to determine the resistance of *Bacillus pluton* when suspended in honey to the direct rays of the sun. In these experiments a honey suspension of the organism obtained from the stomachs of infected bees is exposed to the sun in a Petri dish with the top removed. After intervals, reckoned in hours, inoculation tests are made using healthy larvæ and the direct method. Table VIII contains a summary of the experiments performed:

TABLE VIII.—*Resistance of Bacillus pluton suspended in honey and exposed to direct sunlight*

Date of inoculation.	Period of exposure.	Results of inoculation.
1915.	*Hours.*	
Aug. 24	1	European foulbrood produced.
Do	2	Do.
Do	3	Do.
Aug. 3	3	No disease produced.
Aug. 20	3	Do.
Sept. 13	3	Do.
Sept. 19	4	Do.
Aug. 20	5	Do.
Sept. 14	5	Do.
Do	6	Do.
Sept. 11	7	Do.
Sept. 14	8	Do.
Do	9	Do.
Sept. 28	10	Do.

It is shown by the experiments recorded in Table VIII that in direct sunlight *Bacillus pluton* was destroyed in from 3 to 4 hours.

The results obtained by the experiments summarized in the last three tables above, it will be noted, show that *Bacillus pluton* is susceptible to the destructive effects of the direct rays of the sun; that the resistance of the organism suspended in honey is about equal to its resistance when suspended in water; and when dry the resistance is considerably greater than when suspended in either water or honey. It is to be expected that the period required for the destruction of the organism by the rays of the sun will vary with the intensity of the rays at the time of the exposure. In the foregoing experiments clear days were chosen and preference was given to the middle of the day for the exposures.

RESISTANCE OF BACILLUS PLUTON TO FERMENTATION

In obtaining data relative to the resistance of *Bacillus pluton* to fermentation, the stomach contents of larvæ sick or recently dead of European foulbrood were suspended in a 10 per cent sugar (saccharose) solution. A bit of soil was added to inoculate it further. Records were made on suspensions fermenting at incubator and room temperatures, respectively. Tables IX and X which follow summarize experiments made:

TABLE IX.—*Bacillus pluton in a 10 per cent sugar solution fermenting at incubator temperature*

Date of inoculation.	Period of fermentation.	Results of inoculation.
	Days.	
Aug. 12, 1916	3	European foulbrood produced.
June 26, 1916	5	No disease produced.
Sept. 2, 1916	7	Do.
Sept. 7, 1915	8	Do.
Aug. 9, 1915	10	Do.
June 30, 1916	15	Do.
July 5, 1915	15	Do.
Aug. 24, 1915	24	Do.

TABLE X.—*Bacillus pluton in a 10 per cent sugar solution fermenting at room temperature*

Date of inoculation.	Period of fermentation.	Results of inoculation.
	Days.	
June 30, 1916	9	European foulbrood produced.
July 17, 1915	10	Do.
Sept. 8, 1915	10	Do.
July 21, 1915	14	Do.
Aug. 25, 1916	16	Do.
July 8, 1916	17	Do.
Sept. 10, 1916	11	No disease produced.
July 5, 1916	14	Do.
Aug. 26, 1916	21	Do.
Aug. 3, 1915	27	Do.
Aug. 9, 1915	32	Do.
Aug. 25, 1915	49	Do.

The experimental results contained in Tables IX and X show that *Bacillus pluton* is destroyed in a fermenting solution. At incubator temperature the virus was destroyed in from 3 to 5 days, and at room temperature it was killed in from 11 to 21 days.

Similar experiments were made in which suspensions in 20 per cent honey solutions were allowed to ferment at outdoor temperature. The records obtained show that *Bacillus pluton* in this environment was still alive and virulent after one month.

RESISTANCE OF BACILLUS PLUTON TO PUTREFACTION

Suspensions of the contents of stomachs from larvæ sick or dead of European foulbrood were made in a 1 per cent peptone solution. Soil was added to inoculate it further. Putrefactive changes were allowed to take place at incubator and room temperatures, respectively. In Tables XI and XII, which follow, are summarized the experiments performed:

TABLE XI.—*Bacillus pluton in the presence of putrefactive processes at incubator temperature*

Date of inoculation.	Period of putrefaction.	Results of inoculation.
	Days.	
June 30, 1916	9	European foulbrood produced.
Sept. 2, 1916	7	No disease produced.
Aug. 15, 1916	8	Do.
Sept. 7, 1915	13	Do.
July 5, 1916	15	Do.
Sept. 10, 1915	16	Do.
July 8, 1916	18	Do.
Aug. 23, 1915	19	Do.
Aug. 30, 1915	26	Do.

TABLE XII.—*Bacillus pluton in the presence of putrefactive processes at room temperature*

Date of inoculation.	Period of putrefaction.	Results of inoculation.
	Days.	
Aug. 4, 1914	8	European foulbrood produced.
July 17, 1915	10	Do.
July 5, 1916	14	Do.
July 23, 1915	16	Do.
Aug. 14, 1914	18	Do.
Sept. 17, 1915	18	Do.
Aug. 25, 1916	18	Do.
Sept. 2, 1916	26	Do.
Aug. 3, 1915	27	Do.
Aug. 28, 1916	21	No disease produced.
Sept. 1, 1914	35	Do.
Sept. 16, 1914	51	Do.
Aug. 12, 1916	52	Do.

As shown by Tables XI and XII *Bacillus pluton* is destroyed in the presence of putrefactive processes. At incubator temperature it resisted the effects of these processes for from 7 to 13 days and at room temperature for from 21 to 35 days.

During August and September, 1916, preliminary experiments were made testing the resistance of *Bacillus pluton* to putrefaction at outdoor temperature. The parasite was alive and virulent after 40 days. The maximum period during which it will remain so has not been determined.

VIABILITY OF BACILLUS PLUTON IN HONEY

Honey suspensions of *Bacillus pluton* from the stomach contents of larvæ sick or recently dead of European foulbrood were made and distributed in flasks each containing about 300 c. c. These were allowed to stand at room temperature shielded from the light. At intervals thereafter colonies free from the disease were inoculated each with the contents of a single flask. A summary of the experiments is contained in Table XIII:

TABLE XIII.—*Resistance of Bacillus pluton in honey at room temperature*

Date of inoculation.	Period in honey.		Results of inoculation.
	Months.	*Days.*	
May 22, 1915		4	European foulbrood produced.
June 12, 1915		25	Do.
July 23, 1915	1	6	Do.
June 25, 1915	1	11	Do.
Aug. 23, 1915	1	15	Do.
Aug. 3, 1915	1	17	Do.
July 12, 1915	1	25	Do.
Aug. 23, 1915	2	7	Do.
Sept. 10, 1915	2	25	Do.
Aug. 16, 1916	3	0	Do.
May 19, 1916	7	0	No disease produced.
May 4, 1915	7	17	Do.
June 7, 1913	8	0	Do.
June 13, 1913	8	0	Do.
May 13, 1915	8	25	Do.
May 14, 1915	8	26	Do.
May 22, 1915	9	5	Do.
May 24, 1915	9	5	Do.
July 31, 1916	9	11	Do.
May 15, 1916	10	6	Do.

Experimental evidence recorded in Table XIII shows that the virus of European foulbrood when suspended in honey at room temperature ceased to be virulent in from 3 to 7 months.

VIABILITY OF BACILLUS PLUTON IN POLLEN

Preliminary experiments were made to determine the viability of *Bacillus pluton* in pollen. Pollen is removed from brood-comb, and an aqueous suspension of the organism obtained from the stomachs of larvæ sick or recently dead of the disease is added to it until a moderately thick, pastelike mass is obtained. This is distributed in Petri dishes and allowed to stand at room and refrigerator temperatures, respectively. After different intervals of time the contents of a single dish, after being suspended in water, are added to about 300 c. c. of sirup and the suspension is fed to a colony, using the indirect method. The results show that *Bacillus pluton* was virulent after 7 months at room temperature and for more than 10 months in the refrigerator. The maximum period during which the organism will remain alive in these two environments has not been determined.

RESISTANCE OF BACILLUS PLUTON TO CARBOLIC ACID

Preliminary experiments were made to determine the effect of carbolic acid on the virus of European foulbrood. An aqueous suspension of the contents of the stomachs of larvæ sick or dead of the disease is first made. A measured quantity of this suspension is added to an equal quantity of an aqueous suspension of carbolic acid of a strength twice that desired in the experiment. After shaking, it is allowed to stand at room temperature. At intervals brood free from the disease is fed a bit of this suspension, using the direct method. Table XIV summarizes the experiments performed:

Table XIV.—*Effect of carbolic acid on Bacillus pluton*

Date of inoculation.	Strength of solution.	Period of suspension.	Results of inoculation.
	Per cent.	*Days.*	
Aug. 22, 1914	½	¾	European foulbrood produced.
Aug. 14, 1914	½	1	Do.
July 3, 1915	½	4	Do.
Aug. 21, 1914	½	8	Do.
Sept. 4, 1914	½	18	No disease produced.
June 29, 1915	1	[1]5	European foulbrood produced.
July 3, 1915	1	4	No disease produced.
June 29, 1915	2	[1]5	Do.
Aug. 22, 1914	2	[1]18	Do.
Aug. 14, 1914	2	1	Do.
Aug. 17, 1914	2	4	Do.
Aug. 25, 1914	2	4	Do.
Aug. 22, 1914	2	9	Do.
June 29, 1915	4	[1]5½	Do.

[1] Hours.

The experiments outlined in Table XIV show that *Bacillus pluton* withstood a one-half per cent solution of carbolic acid for 8 days but not for 18 days; that it withstood 1 per cent for 5 hours but not for 4 days; and that it was destroyed by 2 and 4 per cent solutions, respectively, in less than 6 hours. Probably it is destroyed by these latter strengths in considerably less time than this.

It is seen by these preliminary experiments that *Bacillus pluton* is destroyed easily by carbolic acid as a disinfectant. As a drug, however, less can be expected of it, inasmuch as a strength twice that which the bees will accept in honey (Table XV) requires days to destroy the germ. While the fact does not furnish conclusive proof of the value of carbolic acid as a drug, it indicates what might be expected of it in the treatment of the disease.

In using the results recorded on the foregoing pages for the purpose of destroying the virus of European foulbrood and controlling the disease in practical apiculture, it must be borne in mind, as has been urged in the discussions on the other bee diseases, that due allowance must be made by the beekeeper for variations which always occur. These, however, are relatively slight and can be met readily. In the destruction of the virus through heating, for example, the temperature can be raised a few degrees above that which is found to be the minimum required, or the time can be extended somewhat. Similarly for the other destructive agencies the effectiveness of the process can be increased.

EFFECT OF DRUGS ON EUROPEAN FOULBROOD

Preliminary experiments have been made to obtain data relative to the effect of drugs on *Bacillus pluton*. In conducting the experiments a suspension of the stomach contents of larvæ sick or recently dead of European foulbrood is made in an aqueous solution of the drug. This is added to diluted honey and healthy brood is fed this suspension. In some instances the direct and in others the indirect method was followed. In Table XV are summarized the experiments which were performed:

TABLE XV.—*The effect of drugs on European foulbrood*

Date of experiment.	Drugs.	Strength.	Results of inoculation.
1916.			
July 11	Betanaphthol	1:2000	European foulbrood produced.
May 31	do	1:1000	
June 7	do	2:1000	
July 11	Carbolic acid	1:2000	
June 21	do	1:1000	
Do	do	2:1000	
May 31	Oil of eucalyptus	4:1000	
July 11	do	4:1000	
June 7	Formic acid	1:1000	
July 11	do	3:1000	
Do	Salicylic acid	1:2000	
May 31	do	1:1000	
June 7	do	2:1000	
July 11	Salol	1:2000	
May 31	do	1:1000	
June 7	do	2:1000	
July 11	Quinin	2:1000	
May 31	do	4:1000	
June 7	do	10:1000	

It will be observed from Table XV that European foulbrood was produced in all cases in which larvæ were fed a suspension of *Bacillus pluton* in sirup medicated with betanaphthol, carbolic acid, eucalyptus, formic acid, salicylic acid, salol, and quinin (bisulphate of quinin), respectively, in the proportions noted.

The strongest solutions of the drugs used in the experiments are in most instances approximately the maximum proportion of the chemical in honey that will be taken by the bees. These preliminary results indicate that drugs should not be depended upon, for the present at least, in the treatment of European foulbrood, and emphasize the fact that beekeepers should make sure that the value of a drug has been demonstrated fully before it is used.

TRANSMISSION OF EUROPEAN FOULBROOD

While there is yet much to be learned concerning the transmission of European foulbrood, the data at hand relative to this important phase in the study of the disease justify certain statements in regard to it. The disease can be produced experimentally by feeding a healthy colony the crushed larvæ sick or dead of the disease, suggesting that infection takes place by way of the alimentary tract.

Through the study of microtome sections of such larvæ, it has been conclusively proved that infection takes place in this way. The fact is naturally one of special moment in the solution of the transmission of the disease. There is a tendency on the part of adult bees to remove sick and dead larvæ from the brood comb. This is done largely at least in a piecemeal manner. Were the fate of the fragments removed known definitely the solution of the problem naturally would be aided greatly.

If infective material thus removed were fed to susceptible healthy larvae, disease would result. On the other hand should the fragments of diseased larvæ be stored with the honey of the hive or with the pollen, or consumed by the adult bees, or by larvæ later in the feeding stage, the chances that such material would ever reach susceptible larvæ to cause infection are very much reduced. Stored in honey the virus remains virulent only a few months (p. 24); in pollen, however, it remains virulent much longer (p. 24). Drying within the hive *Bacillus pluton* would probably remain alive more than a year (p. 19).

The chances that any portion of the infectious material of any given fragment, if it is removed entirely from the hive by the bees of the colony, and released from them, will be taken up by other bees and carried to healthy brood and cause infection are comparatively slight. If thus removed and exposed to the direct rays of the sun, the virus will be destroyed within a few hours (p. 19); or if subjected to fermentative or putrefactive processes it will be destroyed in a few weeks (p. 23). If *Bacillus pluton* is present in honey extracted from diseased colonies it will be destroyed within a few months while in storage (p. 24). It is seen, therefore, that in nature there are many means that destroy the virus of European foulbrood and thus limit the spread of the disease.

All of the colonies of the experimental apiary used in making the inoculations cited in the present paper had free access to the fields and there was no evidence at any time of the transmission of the disease from infected to healthy colonies. This fact supports the conclusion that the disease is not spread by way of flowers visited by bees from healthy colonies which had been visited previously by bees from diseased ones. The fact further indicates that if the disease is transmitted at all by way of the water supply of the bees, it takes place to a limited extent only. The fact still further indicates that if drones or straying or drifting workers transmit European foulbrood they do so to a slight extent only. If these observations are at variance with the experience of the practical beekeepers, as the writer has been informed that they are, they will probably be of particular interest.

Observations made during the present studies indicate that queens from European foulbrood colonies are not likely to transmit the disease when introduced into healthy colonies. The experiences further show, and the facts in general regarding the disease support the conclusions, that the infection will not be transmitted by the hands or clothing of the beekeeper, or by visitors to the apiary when the manipulations ordinarily practiced are followed. Tools and equipment used about the apiary are not to be feared unless they supply a source for robbing. Hives which have housed infected colonies are not likely to be a medium for the spread of the disease.

Robbing of infected colonies is the most fruitful source of infection. A colony weakened by disease (p. 5) becomes a prey for other bees. Infectious material is carried to other colonies, thereby transmitting the infection. Manipulations in the apiary, whereby brood combs from diseased colonies are placed in healthy ones, are another fruitful source for the transmission of the disease. Preliminary work[1] indicates that stored brood combs from European foulbrood colonies may transmit the disease after a considerable period.

The disease, it would seem, might be spread through the medium of honey from infected colonies. The danger from this source, however, probably has been overestimated at times (p. 23). That pollen stored in the comb would serve as a protection to *Bacillus pluton*, if the parasite were lodged with it, has been determined (p. 24).

DIAGNOSIS

The diagnosis of European foulbrood offers more difficulty than does that of either American foulbrood or sacbrood. It can usually be made, however, from the symptoms alone. Inasmuch as these symptoms (p. 4) are rather varied, much care should be exercised in diagnosing the disease.

The appearance of the adult bees does not aid in the diagnosis. A weak colony should arouse suspicion. Increased suspicion is justified when no other readily discernible cause for the weakness is to be observed. The disease may be present, however, in a strong colony. Such a case may be one of recent infection or one which late in the recovery from the disease has gained in strength. It may be, however, a colony which has suffered only a slight attack of the disease.

The following outstanding gross characters are often sufficient for a diagnosis: The dying of the brood before the time for capping (Pls.

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[1] Brood combs were removed from European foulbrood colonies in October, 1914, and stored in the laboratory. In May, 1915, one frame of brood comb was placed in each of two colonies with the result that European foulbrood was produced in both instances. When a frame of the comb was placed in the colony in May, 1916, no disease resulted. After 6 months the combs were still able to transmit the disease; after 18 months they did not. These experiments are not sufficient to justify definite conclusions but are suggestive.

II, III, IV), the yellow hue of the larvæ more recently dead, and the brown shade of those longer dead, the irregularity of the brood (Pl. I), and the absence of a disagreeable odor.

Not infrequently, however, the diagnosis is not so simple. During recovery from the disease scales (Pl. V, F, I) of larvæ dying in capped cells may be the only remains of diseased brood to be found, all of the younger larvæ having been removed by the bees. These scales[1] are, as a rule, comparatively few in number and resemble somwhat those of American foulbrood, but would rarely be mistaken for those of sacbrood. In these cases a diagnosis can be made frequently by a microscopic examination alone. Cultures, however, are needed in some instances.

Special attention is needed in cases of early infection and in other instances where only a small amount of diseased brood in uncapped cells is present (Pl. I, A). The symptoms manifested by larvæ sick or only recently dead of the disease furnish often the readiest and most conclusive evidence of the presence of the disease. Larvæ of the age at which they comfortably fill the bottom of the cell exhibiting increased peristalsis-like movements of the body suggest European foulbrood. Increased transparency of larvæ of this age (Pl. II, B) is also suggestive. The presence of a white or yellowish-white mass within the stomach (midgut) as seen through the dorsal median line of the body is strong evidence of the presence of the disease. If on puncturing the body of larvæ nearly dead or only recently dead the contents of the stomach flows out as a fluid and more or less finely granular mass, the fact furnishes further evidence of European foulbrood.

A symptom which is pathognomonic of the disease is to be seen in larvæ that have been infected somewhat more than two days, but wherein the disease has not reached an advanced stage. The test (15) involves the removal of the stomach contents, which consist of a bacterial mass, together with a small amount of larval food and a clear envelope (Pl. VIII, a, b, c). The slight tension necessary to remove the contents stretches the envelope and breaks the whitish bacterial mass into a number of fragments.

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[1] The number of larvæ that die of European foulbrood in capped cells after assuming the endwise position represents a very small percentage of the brood that dies of the disease. These remains may be found in practically all colonies in which the disease has been present for a sufficiently long period and in which a considerable amount of dead brood has resulted. Before becoming dry they are somewhat viscid and are less easily removed than are those of larvæ dying at an earlier age. These and the scales resulting from them are used in diagnosis principally (1) when the younger larvæ sick or dead of the disease have been removed, (2) when a demonstration of the presence of *Bacillus alvei* is desired, and (3) when both European foulbrood and American foulbrood infection is suspected. Such a double infection has been encountered in the writer's experience very rarely. In making diagnoses, therefore, after European foulbrood has been found in the sample American foulbrood is seldom looked for.

By one or more of these colony symptoms manifested by larvæ sick or only recently dead of the disease the experienced can diagnose European foulbrood definitely without a microscopic examination. The methods not only give definite results, but are also easy of application. They have been indispensable in much of the writer's experimental work and it is believed that the beekeeper will find them to be valuable in practical apiculture where other gross methods fail.

BACTERIOLOGICAL EXAMINATION

The findings from microscopic examinations and from cultures have been set forth in an earlier publication (10). These are always adequate for a definite diagnosis when a suitable sample is at hand. *Bacillus alvei* (p. 11) (fig. 2; Pl. VII, D, F) frequently overshadows all other species. In larvæ sick of the disease *Bacillus pluton* (Pl. VII, A, B) overshadows all others. With experience one learns to recognize this species in stained preparations. The individuals are seen frequently in groups. They are more or less lancet shaped, and a variation in size is often sufficient to be noticeable (fig. 1).[1] In larvæ nearly dead and in those only recently dead *Bacterium eurydice* (p. 13) (fig. 4; Pl. VII, C) is frequently encountered. *Streptococcus apis* (p. 12) (fig. 3; Pl. VII, E) occurs in a small number of cases. *Bacillus orpheus* (p. 14) (fig. 5; Pl. VII, H), *B. vulgatus*, and *B. mesentericus* are occasionally encountered. While *B. pluton* is present in all cases of European foulbrood, not infrequently in routine examinations it is so masked by the secondary invaders that the microscopic examination fails to reveal it. In many cases *B. alvei* and *B. orpheus* are recognized microscopically. Cultures are necessary for the differentiation of *B. vulgatus* and *B. mesentericus*. In many cases cultures are needed to differentiate *Strep. apis* and *B. pluton*. *Strep. apis* grows on the ordinary media, *B. pluton* does not.

DIFFERENTIAL DIAGNOSIS

AMERICAN FOULBROOD

American foulbrood is recognized by the death of larvæ in capped cells and of pupæ soon after transformation, the viscidity of the decaying remains of the brood, and the "foulbrood" odor which is frequently present. The presence of the spores of *Bacillus larvae* in large numbers and the absence of other species is conclusive proof of American foulbrood.

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[1] Smears made from larvæ sick of European foulbrood and quite early in the course of the disease were selected in making a study of the morphology of *B. pluton*. These were stained with iron hematoxylin. In smears made from dead larvæ and stained with carbol fuchsin, as is usually done, the pointed ends and the more or less rod-shaped forms are less prominent than illustrated in figure 1.

SACBROOD

Sacbrood is recognized by the death of larvæ after capping, by the saclike appearance, the watery granular consistency of the larval remains, and the absence of viscidity. The absence of microorganisms characterizes the microscopic picture in sacbrood.

OTHER CONDITIONS

Conditions referred to as chilled brood, overheated brood, and starved brood must be differentiated from European foulbrood. This can usually be done with little difficulty by a comparison of the symptoms present with those of European foulbrood. The history of the case is of much value. Brood dying after being removed from the hive and before examination is made shows often an interesting similarity to European foulbrood. *B. alvei* and *B. pluton* are not found in these conditions. The absence of bacteria, or their presence in small numbers only, and a lack of uniformity of the species when present, characterize the bacteriological findings in these cases.

PROGNOSIS

There is no uniformity in the prognosis in European foulbrood. The diseased colony may recover completely from the infection, suffering only a slight loss in strength as a result of it; the colony may recover but sustain considerable loss; or it may die out entirely, as a result of the disease. The infection may spread only slightly to other colonies of the apiary or the entire apiary may become infected. The losses sustained vary from slight to total. The tendency for European foulbrood to disappear is greater after midsummer than before.

Whether a larva once infected ever recovers from this disease is not known, but the evidence at hand indicates that it may. This seems to be especially probable when the infection takes place during the latter part of the feeding period of the larva. Queen larvæ are susceptible to infection, but sufficient data are wanting from which to estimate the extent to which queenlessness may result from the disease. In experimental colonies queens have been reared in the presence of a considerable amount of European foulbrood infection.

The prognosis for the colony in the case of European foulbrood may be said, therefore, to vary from very good to very grave, many recovering entirely from the infection without treatment and without appreciable losses, while others rapidly decline and finally die out.

SUMMARY AND CONCLUSIONS

The following is a brief summary of facts regarding European foulbrood, together with some conclusions based upon them:

1. European foulbrood is an infectious brood disease of bees caused by *Bacillus pluton.*

2. All larvæ—worker, drone, and queen—are susceptible to the disease; adult bees are not.
3. Man evidently is not susceptible to infection with *Bacillus pluton* nor are the experimental animals.
4. As far as is known insects other than bees are not susceptible.
5. Brood can be infected by feeding the colony a suspension of crushed larvæ sick or dead of the disease. This is described in the present paper as the indirect method.
6. The virus contained in a single larva recently dead of European foulbrood will produce a considerable amount of disease when fed to a colony.
7. The larvæ can be infected also by a more direct method. A fraction of a drop of a suspension of the stomach contents of a larva sick of the disease added with a capillary pipette directly to the food surrounding the larva to be inoculated will result in infection.
8. *Bacillus pluton* gains entrance to the larva by way of the mouth. The growth and multiplication of the parasite take place within the stomach (mid-intestine) of the larva and do not, during the life of the larva, get beyond the peritrophic membrane. The tissues, therefore, are not invaded by it.
9. The secondary invaders in European foulbrood, *Bacillus alvei*, *Streptococcus apis*, *Bacterium eurydice*, and *Bacillus orpheus*, rarely, if ever, invade the tissues until the larva is dead or nearly so. In a few instances in microtome sections rod forms have been encountered in the act of invading the tissues of living larvæ. The species, however, was not determined definitely.
10. The period of incubation is slightly less than 3 days.
11. Brood is susceptible to infection at all seasons of the year.
12. More brood die of the disease during the first half of the brood-rearing season than during the second half.
13. The writer has examined samples of the disease from Canada and the United States. From written reports it seems quite certain that it occurs also at least in Denmark, England, Germany, France, and Switzerland.
14. Occurring as it does in this somewhat wide range of climatic conditions, the presence of the disease in any particular locality can not be attributed entirely to the prevailing climatic conditions.
15. The quality of food obtained by the bees does not affect greatly, if at all, the course of the disease in the colony, although the quantity may affect it to a variable extent.

16. Experimental colonies may be inoculated and kept in the apiary without transmitting the disease to others. This fact is of special importance, not only in connection with the technique of making studies on the disease, but also in the control of the malady.
17. The thermal death point of *Bacillus pluton* suspended in water is approximately 63° C. maintained for 10 minutes.
18. When suspended in honey *Bacillus pluton* is destroyed in 10 minutes at approximately 79° C.
19. Drying at room or incubator temperature *Bacillus pluton* remains alive and virulent for approximately one year.
20. When dry, *Bacillus pluton* resisted the direct rays of the sun for from 21 to 31 hours.
21. When suspended in water *Bacillus pluton* was destroyed by the direct rays of the sun in from 5 to 6 hours.
22. When suspended in honey and exposed to the direct rays of the sun *Bacillus pluton* was destroyed in from 3 to 4 hours.
23. In the presence of fermentative processes in a 10 per cent sugar solution *Bacillus pluton* was destroyed in from 3 to 5 days at incubator temperature and in from 11 to 21 days at room temperature.
24. In a fermenting honey solution outdoors *Bacillus pluton* was still alive and virulent after one month.
25. In the presence of putrefactive processes at incubator temperature *Bacillus pluton* was destroyed in from 7 to 13 days and at room temperature in from 21 to 35 days.
26. In a putrefying medium at outdoor temperature *Bacillus pluton* remained alive and virulent for more than 40 days. The maximum period has not been determined.
27. In honey at room temperature *Bacillus pluton* ceased to be virulent in from 3 to 7 months.
28. Mixed with pollen, *Bacillus pluton* remained alive and virulent for more than 7 months at room temperature and more than 10 months at refrigerator temperature, the maximum time not being determined.
29. In one-half per cent carbolic acid solution *Bacillus pluton* was destroyed in from 8 to 18 days; in 1 per cent it was destroyed in from 5 hours to 4 days, and in 2 and 4 per cent in less than 6 hours. The probability is that at these higher strengths of the solution minutes rather than hours are sufficient for the destruction of the virus.
30. Experimental evidence indicates that at the present time drugs should not be depended upon in the treatment of European foulbrood.

31. Robbing from diseased colonies of the apiary or from neighboring apiaries is the most likely manner in which European foulbrood is transmitted in nature.
32. Brood-combs containing diseased brood, if given to a healthy colony, serve as a medium for the transmission of the disease.
33. European foulbrood is not likely to be transmitted by queens or drones. Whether they ever do so has not been demonstrated.
34. As a rule a hive which has housed a European foulbrood colony should not be considered as a fruitful source of infection. The facts indicate that often such hives could be used with impunity for housing colonies without treatment. Flaming them inside certainly removes all danger.
35. The transmission of European foulbrood by way of flowers, visited by bees from diseased colonies and subsequently by those from healthy ones, is not to be considered as a likely source of infection. Whether the water supply is ever a source of danger is not known. It is evidently not a fruitful source.
36. The disease is not likely to be transmitted through the medium of the clothing or hands of the apiarist.
37. Tools and bee supplies in general do not serve as means for the transmission of the disease in the absence of robbing from such sources.
38. It is usually possible to diagnose European foulbrood from the symptoms alone. A definite diagnosis can be made from suitable samples by bacteriological methods.
39. The prognosis in European foulbrood varies from very good to exceedingly grave. The tendency for a colony to recover entirely from the disease is much greater than in American foulbrood.
40. Considered from the technical point of view, much is yet to be learned concerning European foulbrood. For practical purposes, however, it can be said that sufficient knowledge has been gained to make it possible for the beekeeper to devise a treatment which will be logical, efficient, and at the same time economical.

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EXPLANATION OF PLATES

Plate I

Brood-combs containing larvæ that are sick and others that are dead of European foulbrood, showing the irregular appearance of the brood. About one-half natural size.

A.—The dead larvæ have all been removed. Some of the remaining larvæ are sick, others are not infected. The disease was produced by experimental inoculation.

B.—Many of the dead larvæ have not been removed. The comb had been out of the colony for a considerable period. The larvæ that are quite young showing abnormal position and appearance are not sick or dead of European foulbrood, but are so as a result of the comb being away from the colony. Disease was produced by experimental inoculation.

C.—The comb was taken from a colony in which the disease had appeared in nature and not as the result of artificial inoculation. Before being photographed the brood-comb had been out of the hive for a few days. Aside from the larvæ which are dead of European foulbrood, other larvæ present are dead from lack of attention by adult bees—starvation, exposure, and other causes.

Plate II

A.—Live larva showing first symptoms of European foulbrood. The turgidity is slightly less than in a healthy larva (D).

B.—Live larva showing early symptoms of European foulbrood. The body is more transparent than that of a healthy larva (D). Small opaque areas give it a punctate appearance.

C.—Larva dead of European foulbrood contained within a chitinous envelope filled with a watery-appearing fluid.

D.—Healthy larva of the earliest age at which larvæ die of European foulbrood. Turgidity marked.

E.—European foulbrood larva which may or may not be dead. Surface less glistening than in healthy larvæ. Marked turgidity lost. Prominence of tracheæ not increased.

F.—Scale formed by drying of larvæ dead at early age. Prominence of tracheæ marked.

G.—View of healthy larva in normal position with roof of cell removed. Larva turgid. Surface glistening.

H.—Larva sick with European foulbrood. Lack of turgidity and increased prominence of tracheæ observed.

I.—European foulbrood larva which may or may not be dead. Less turgidity, a relative dullness in the surface appearance, and punctate condition present. Similar to E.

Plate III

A.—Healthy larva immediately preceding the age at which the capping of the cell is done. Dorsal surface turned toward the observer. The narrow transparent area along the dorsal median line is prominent.

B.—Larva dead of European foulbrood of the same age as A. The turgidity, glistening surface, and transparent area are less marked.

C.—Larva dead of European foulbrood partly coiled and partly endwise in cell.

D.—Healthy larva near the age at which capping takes place.

E.—Dorsolateral view of a larva dead of European foulbrood. The ends are directed toward the bottom of the cell.

F.—Larva dead of European foulbrood. The body occupies a spiral position in the cell.

G.—Healthy larva approaching the age at which capping takes place.

H.—Lateral view of larva dead of European foulbrood seen with the roof of the cell removed. The ends are directed toward the bottom and the dorsal surface toward the mouth of the cell.

I.—Dead larva similar to H but having been dead somewhat longer.

PLATE IV

A.—Young larva dead of European foulbrood. The chitinous capsule and tracheæ are prominent.

B.—Fragments of young larva dead of European foulbrood, a portion having been removed by adult bees after its death.

C.—Lateral view of larva dead of European foulbrood, the roof of the cell having been removed. The ends in this instance are directed more or less toward the mouth of the cell.

D.—Lateroventral view of larva dead of European foulbrood. The body lies with the dorsal portion against the floor of the cell.

E.—Larva dead of European foulbrood lying on the floor of the cell in somewhat lengthwise position.

F.—Scale of European foulbrood larva which had occupied a somewhat spiral position in the cell.

G.—Scale of a European foulbrood larva which had occupied a position somewhat as shown in D. This scale and the one shown in F can be removed intact rather easily and without tearing the wall of the cell.

PLATE V

Larvæ (prepupæ) of bees dead of European foulbrood which had already assumed before death a lengthwise position in the cell.

A.—Fragment of European foulbrood soon after death. A portion of the larva has been removed by the adult bee.

B.—Entire cap of cell containing larva dead of European foulbrood.

C.—Punctured cap of cell containing the remains of a larva dead of European foulbrood.

D.—End view of larva dead of European foulbrood.

E.—End view of larva dead of European foulbrood, lying with its dorsal surface against the floor of the cell. Considerable drying of the remains has taken place.

F.—End view of scale of European foulbrood larva which had reached before death the age at which the endwise position in the cell is assumed.

G.—Ventral view of European foulbrood larva. Stage similar to D. Turgidity is lost to a large extent and the segmented markings are less distinct than in healthy larvæ.

H.—Larva which has been dead of European foulbrood for a longer period than illustrated in G. The ridge and furrows indicating the segments of the body are not marked.

I.—Scale of European foulbrood similar to F. The larva before death had reached the endwise position in the cell. These scales resemble very much those of American foulbrood. They are more easily removed, however, do not adhere so closely to the floor of the cell, and are more rubberlike in consistency, breaking less readily than those of American foulbrood.

PLATE VI

A view of the experimental apiary of 54 colonies in which the inoculation experiments made during the summer of 1915 were conducted.

PLATE VII

Photomicrographs illustrating the more commonly encountered bacteria in European foulbrood.

A.—*Bacillus pluton:* A smear from the stomach of a larva sick with European foulbrood. Note the paired forms and short chains. These forms are numerous in a recent infection, suggesting the organism in the process of multiplication. The lancet-shaped form is by far the predominant one in all later stages of the disease. × 1000.

B.—*Bacillus pluton:* A smear from a larva quite recently infected. The multiplying paired forms are at this stage present almost exclusively. × 1000.

C.—*Bacterium eurydice:* Stained preparation from a pure culture on the surface of agar. × 1000.

D.—*Bacillus alvei:* Stained preparation showing spores and spore formation. × 800.

E.—*Streptococcus apis:* Stained preparation from a pure culture. × 800.

F.—*Bacillus alvei:* The peculiar arrangement of the spores as sometimes seen. From a pure culture, the smear having been made by suspending the culture on the slide in normal salt solution. × 1000.

G.—*Bacillus orpheus:* Stained preparation made from a pure culture only a few hours old. Grown on the surface of agar. × 1000.

H.—*Bacillus orpheus:* Stained preparation showing spore formation. Note the stained portion along one side and about both ends of the spore. The stage is soon reached in a culture at incubator temperature. At room temperature it remains in this stage for a considerable period. × 800.

I.—Longisection of a young larva showing early infection in European foulbrood. The bacterial growth is seen as a narrow black area just within the peritrophic membrane on one side of the food mass.

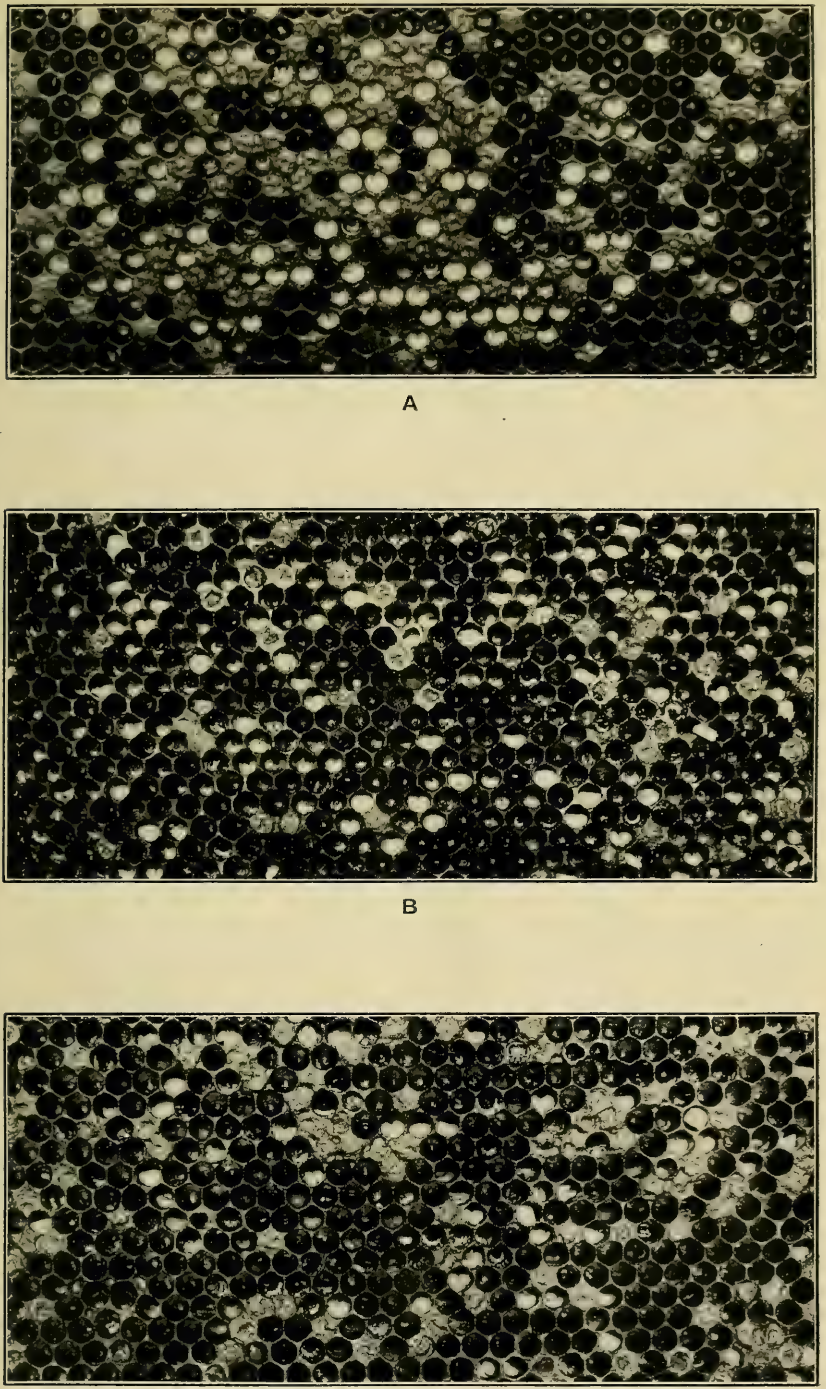
J.—Longisection of larva sick of European foulbrood, showing a later stage of infection than that present in I. The dark area in the food mass shows the bacterial growth. Note that the growth mass does not extend beyond the peritrophic membrane and that it does not extend uniformly along this membrane and throughout the food mass.

K.—Transverse section of larva about the time of its death from European foulbrood infection. Note the bacterial mass along the peritrophic membrane and extending from the membrane into the food mass. As seen within the living larva this bacterial mass in the sick larva is practically white, but is more or less yellowish white when present with larval food material. The gelatinous-like envelope outside the peritrophic membrane and inside the stomach epithelium in healthy larvæ thins out as the disease advances.

PLATE VIII

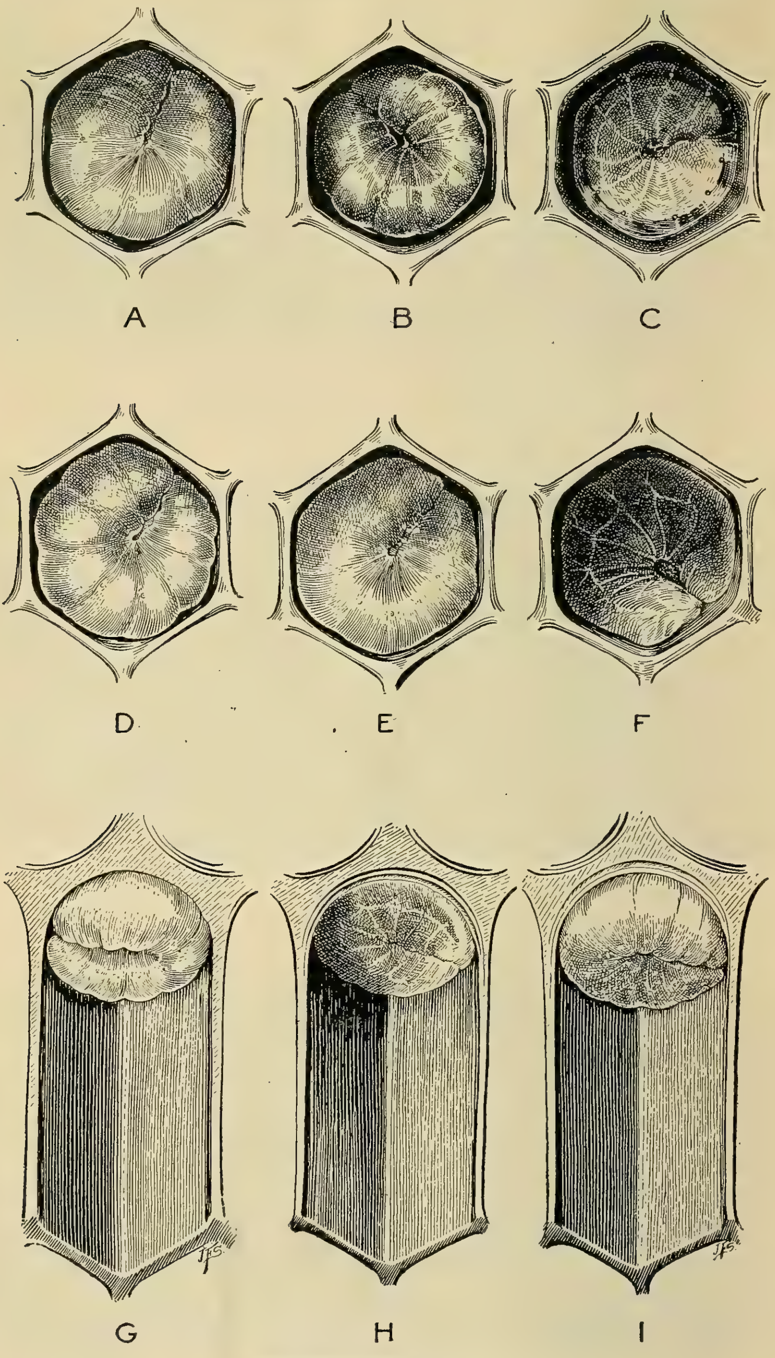
The stomach contents of larvæ sick of European foulbrood removed from the organ. The anterior end of the larva is shown. Fairly early stage of infection (a) showing the white bacterial mass broken into fragments as a result of the tension produced in removing the stomach contents from the organ. A somewhat later stage (b) in the course of the disease, showing the bacterial growth contained in the stomach fragmented, also the mucous or gelatinous envelope surrounding the petritrophic membrane. The stomach contents removed from a European foulbrood larva (c) about the time of its death. The bacterial growth at this time is surrounded by very little other than the peritrophic membrane. When this membrane is ruptured the contents flow out as a thin yellowish-white mass.

PLATE I.



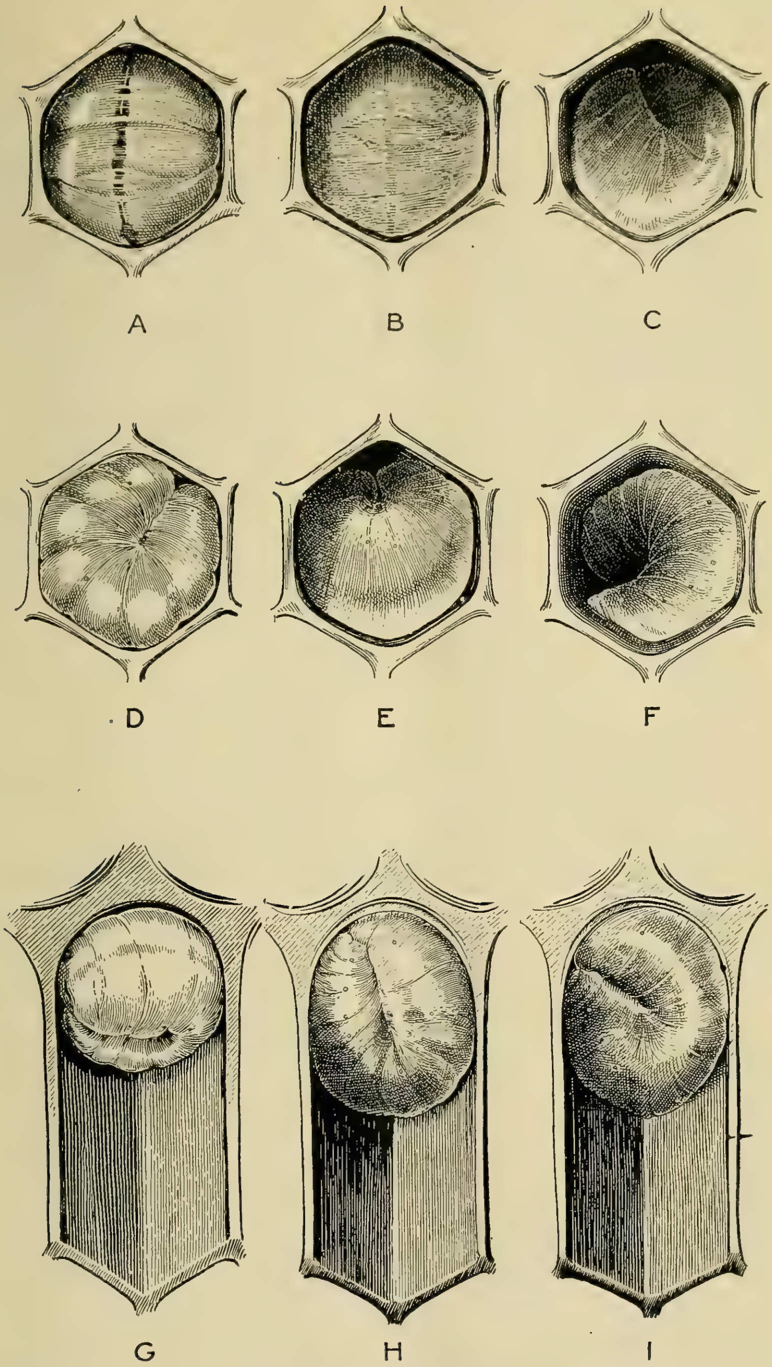
EUROPEAN FOULBROOD.

PLATE II.



EUROPEAN FOULBROOD.

PLATE III.



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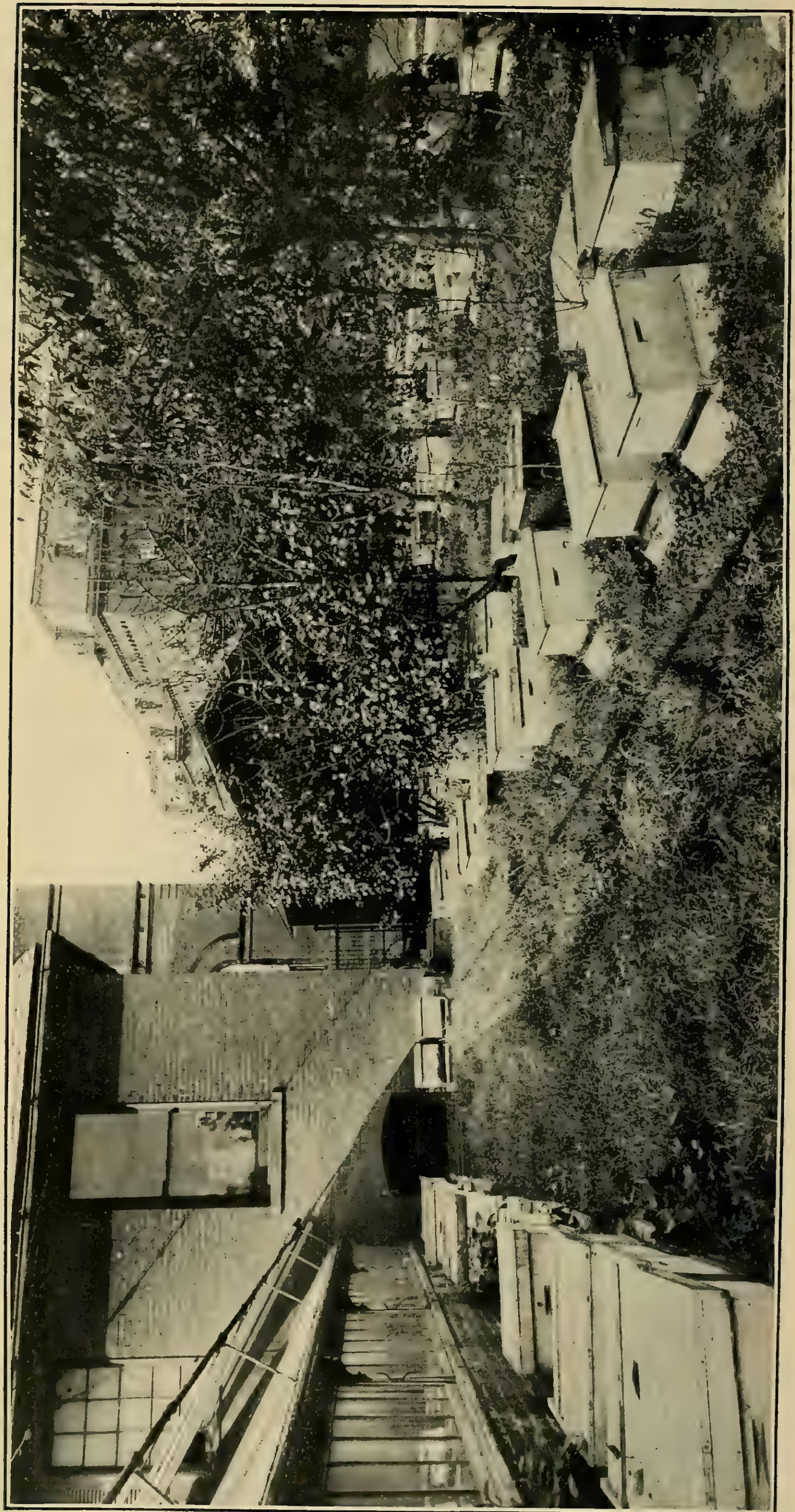

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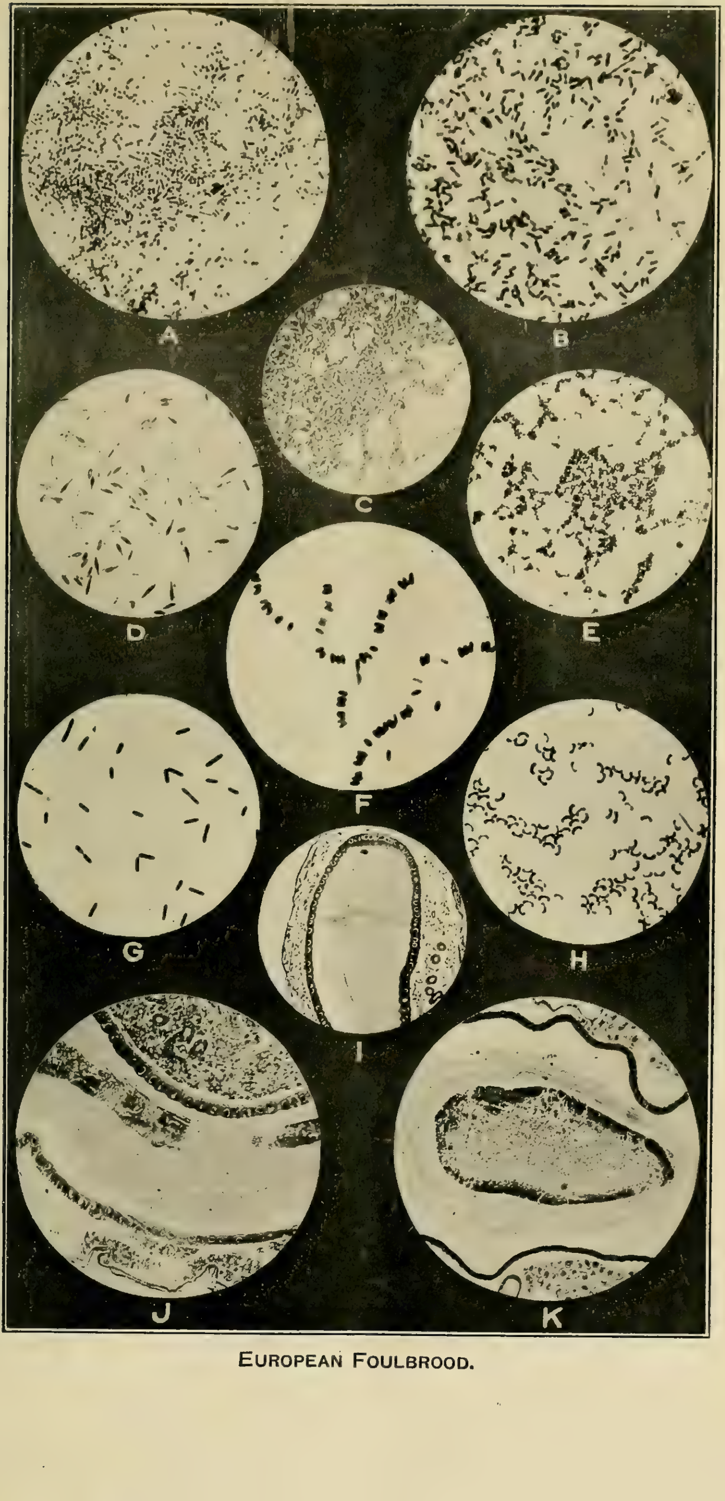

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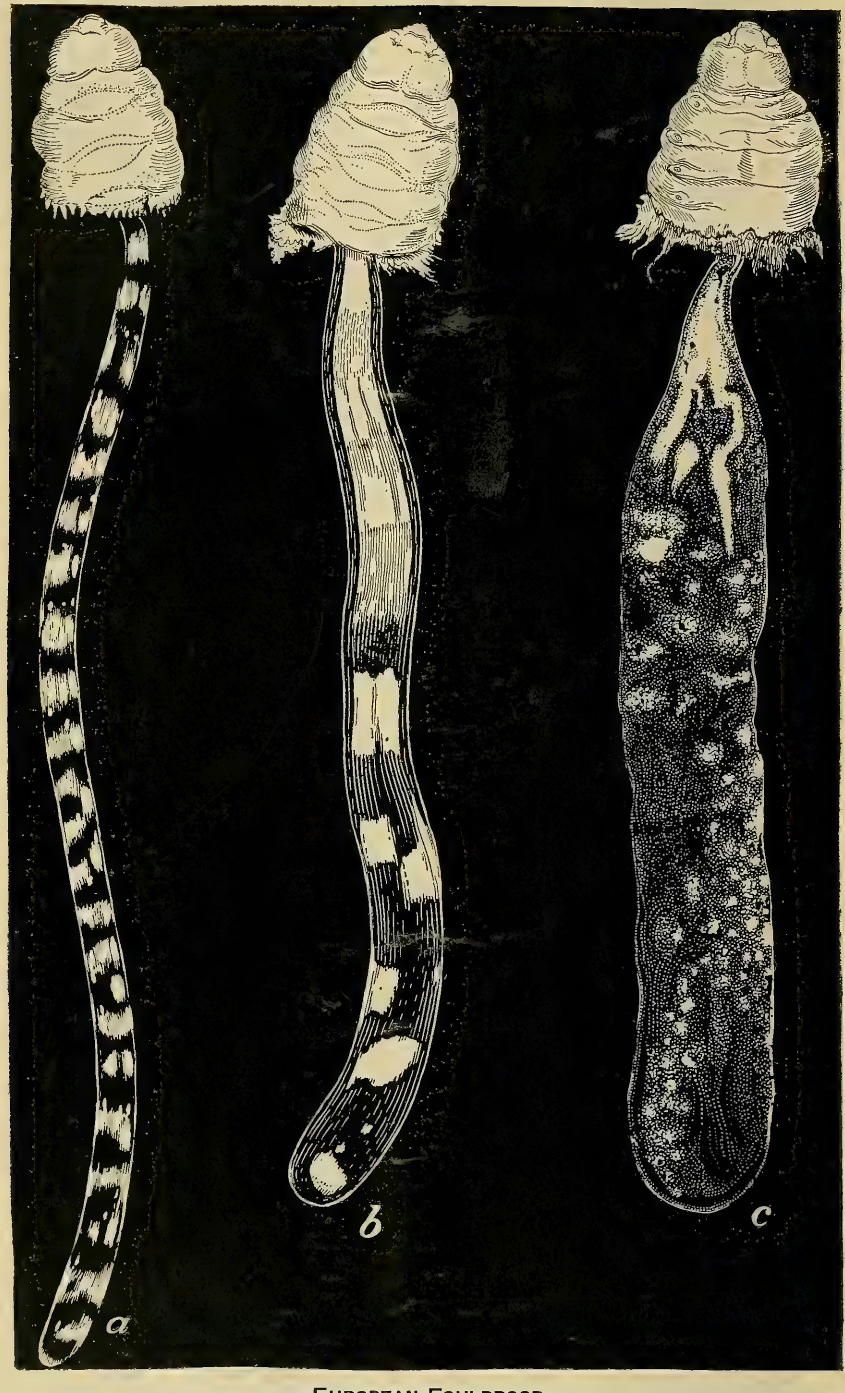

EUROPEAN FOULBROOD.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 811

Contribution from the Bureau of Markets
George Livingston, Acting Chief

Washington, D. C. ▼ **December 5, 1919**

A SYSTEM OF BOOKKEEPING FOR GRAIN ELEVATORS.[1]

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INTRODUCTION.

The close relationship between business success and efficient accounting is recognized by all who are familiar with commercial affairs. The accounting and business practices of marketing enterprises located at country points present relatively difficult problems, because of three facts: First, these enterprises have grown rapidly; second, it is difficult to secure managers who are proficient in bookkeeping; and, third, the volume of business of the individual organizations, in most cases, does not warrant the employment of a skilled bookkeeper.

The general adoption of a uniform system of accounting sufficiently elastic to meet the requirements of organizations operating under varied conditions is believed to be not only practicable, but essential, if the highest degree of success is to be attained. Accordingly a system of accounting was devised by the Bureau of Markets for country elevators and published in 1915. This system has now been adopted by a large number of elevators located in all of the grain-producing States.

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[1] This bulletin supersedes United States Department of Agriculture Bulletin 362: A System of accounts for Primary Grain Elevators, by John R. Humphrey, Assistant in Market Business Practice, and W. H. Kerr, Investigator in Market Business Practice.

With the passage by Congress of the Grain Standards Act, and the consequent promulgation by the Secretary of Agriculture of official standards for grain, a revision of the former bulletin has become advisable. The present bulletin describes the Bureau of Markets system of accounting for country grain elevators, which has been developed in conformity with these standards. In this revision, several features suggested by the practical operation of the system during the last three and one-half years are incorporated.

TYPES OF ELEVATOR ACCOUNTING SYSTEMS.

No system of accounting in grain elevators has been generally accepted as standard. While the principle of double-entry bookkeeping is correctly followed in a limited number of elevators, every variation in type is found, from patented systems to mere handbook entries kept in memorandum form for the benefit of the manager.

All systems of bookkeeping now existing in elevators may be classified under three headings: Complete double-entry systems kept in the elevator office; incomplete systems, consisting of reports and memoranda kept in the elevator office; and systems of reports prepared at the elevator and sent to some outside agency where the records of the company are kept.

Although the third system may furnish definite information, the details of that information, as a rule, are not within easy reach of the men who are most interested in them. For this reason a complete double-entry system kept in the elevator office will be found most satisfactory.

The benefits to be derived from a complete double-entry system of bookkeeping, so constructed that it can be adopted by all elevators, are: First, the possibility of determining, on short notice and with accuracy, each elevator's financial condition; second, the advantage of having readily available statistical data relating to operating costs; third, the possibility of distributing and interchanging valuable statistics among elevators; and, fourth, the training of managers and bookkeepers so that they will obtain a cumulative knowledge of elevator accounting.

DESCRIPTION OF THE SYSTEM AND DIRECTIONS FOR ITS OPERATION.

The complete system includes the following forms:

Page.
Form No. 1. Cash Journal and Purchase and Sales Record 6
Form No. 2 Record of Storage Tickets Issued 4
Form No. 3. Record of Grain Purchases 4
Form No. 4. Record of Grain Shipments and Sales 5
Form No. 5. Record of Hedges 6
Form No. 6. Record of Sales to Arrive 6
Form No. 7. Patronage Ledger 11
Form No. 8. Grain and Merchandise Report 10
Form No. 9. Manager's Report 11
Form No. 10a. Grain Check for Cash Grain 4
Form No. 10b. Grain Check for Stored Grain Purchased 4
Form No. 11. Scale Ticket 3
Form No. 12. Storage Ticket 3
Form No. 13. Sales Ticket 8
Form No. 14. Cash Receipt 9
Form No. 15. Cost Analysis 40

Forms Nos. 1 to 6, inclusive, constituting the Journal, and Form No. 8 are uniform in size and punching and can be held in one loose-leaf binder.

Form No. 7, the Patronage Ledger, is used only where patronage dividends are paid. It is bound in a separate binder.

Form No. 9, the Manager's Report, is used when the books are kept outside the elevator office.

Forms Nos. 9 to 14, inclusive, are recommended for presenting necessary information in convenient form.

In addition to the forms recommended above, a ledger in the usual stock form is necessary.

GRAIN RECEIVING AND SHIPPING RECORDS.

Scale Ticket.—On the Scale Ticket (Form No. 11) is recorded the weight in gross, tare, and net pounds, and gross and net bushels of all grain taken into the elevator, as also dockage where dockage applies. To facilitate auditing, the number of the check or storage ticket, which is issued for the scale ticket, should be entered thereon when the transaction is completed.

The practice of permitting the scale ticket to constitute the only record of grain received, this delaying the completion of the transaction often for many days, should be discouraged by directors of country elevators, because a scale ticket is not evidence of ownership of the grain nor of its having been received into the elevator. In fact, in some States, failure to issue a check or storage ticket on the date of delivery of the grain is made a misdemeanor, punishable by fine and imprisonment.

Storage Ticket.—At the close of each day storage tickets (Form No. 12) should be made out for the unpurchased grain delivered that day. The ticket numbers and the gross, dockage, and net bushels shown on the scale tickets, should be itemized in the space provided therefor on the storage ticket.

Record of Storage Tickets Issued.—All Storage Tickets issued are recorded consecutively on the Record of Storage Tickets Issued (Form No. 2). On this form will be recorded the date, Storage Ticket number, and the dockage and net bushels. Provision is made for classifying the dockage by kind of grain and the net bushels by kind, class, and grade. When storage tickets are purchased, the number of the check issued therefor should be entered in the "Check number" column.

During the season of heavy crop movement this form should be footed daily and the totals carried to the Grain Report (Form No. 8), opposite "Stored this period".

On the storage, purchase, and shipping records (Forms Nos. 2, 3, and 4) only four class segregations are provided under wheat, while the official standards make six segregations. In sections of the country where common white wheat and white club wheat are grown, the class headings shown on the forms should be changed to conform with the classes dealt in.

As it is believed no material advantage would be gained by accounting separately for the five possible classes of oats, no class segregations are provided.

Grain Check.—Elevators storing grain should use one series of grain checks for the purchase of cash grain and another series for the purchase of Storage Tickets (see Forms Nos. 10a and 10b, p. 44), as the two classes of purchases are segregated in the section of the journal devoted to grain purchases. (See Record of Grain Purchases, p. 48.) By the use of two series, both the record of stored grain purchases and the record of cash grain purchases will show an unbroken series of checks, thus facilitating the determination of outstanding checks and auditing the grain purchases. Payment should be made each day for all purchased grain delivered that day. An ordinary form of check often provided by the local bank should be used for disbursements other than for grain.

Record of Grain Purchases.—Elevators which store grain will divide the section in the journal devoted to the Record of Grain Purchases (Form No. 3) into two divisions, Cash Grain Purchases and Stored Grain Purchases.

All checks issued for grain purchased at time of delivery will be entered under Cash Grain Purchases, while checks issued for storage tickets will be entered under Stored Grain Purchases. In some elevators where nearly all grain received is stored for a time, it has been the practice to make out storage tickets for all grain received, even though it be purchased on delivery. This practice is commendable and can be carried out in this system. Where this procedure is followed, there will be no Cash Grain Purchases.

On the Record of Grain Purchases will be entered the date, check number, price, amount of the check, storage deduction, if any, and the cost of the grain, as well as the gross, dockage, and net bushels. The cost of the grain is the amount of the check plus the storage charge.

The net bushels are segregated into kind, class, and grade. All bushel columns should be totaled on dates to correspond with those on which the Record of Storage Tickets Issued is totaled, and the totals carried to the Grain Report opposite "Cash grain purchased this period" or opposite "Stored grain purchased this period."

The Amount, Storage, and Cost columns should be footed at the close of each month and proved by checking the total of the Cost columns against the sum of the Amount and Storage columns.

After the correctness of the monthly footings has been proved, they should be posted to the general ledger as follows: The totals of the various Cost columns, representing the total cost of the respective grains, should be entered on the debit side of the respective grain accounts. The total of the Amount column, representing the total of the grain checks for the month, should be carried to the credit of the Bank account. The totals of the Storage column, representing the income derived from storage collected during the month, should be posted to the credit of the Storage account.

Record of Grain Shipments and Sales.—The Record of Grain Shipments and Sales (Form No. 4, p. 48) carries a record of all cars shipped and the net returns, terminal weights, and terminal grades of each shipment. The data to be entered in the columns headed Date, Shipped to, Car No. and initial, Shipper's grade, and Shipper's weight are taken from the bill of lading at the time of shipment, while those for the remaining columns are taken from the account sales. The totals of the Proceeds columns for each kind of grain should be posted at the end of the month to the credit of the respective grain accounts in the general ledger. The items in the Net proceeds column should be posted individually to the debit of the grain commission accounts indicated in the column provided for the name of the name of the consignee. The totals of the bushels columns should be carried to the Grain Report opposite "Total shipped this period" on dates corresponding with those on which the Record of Storage Tickets Issued and the Record of Grain Purchases are totaled.

In the use of this form it will be found that at the end of the month shipments may be standing out as grain in transit. At the beginning of the following month, it will be necessary to bring all such cars forward, making a note after the previous entry of the shipment, i. e.

Forwarded. By this method the danger of failing to post to the proper commission account the returns on any car will be obviated.

OTHER GRAIN RECORDS.

A Record of Hedges (Form No. 5, p. 50) is essential to the proper hedging of grain and should be kept up to date. On this form columns have been provided in which to record all of the necessary information of hedging transactions. When a purchase or sale of more than 1,000 bushels is recorded, a sufficient number of lines should be left blank to provide space on the opposite side for its cancellation in 1,000 bushel lots. The columns headed P. & S. accounts indicate purchase and sales accounts. All profits on hedges should be entered in the Credit column and losses in the Debit column, and both will be carried individually to the Cash Journal to the debit or credit, as the case may be, of the commission account represented and to the grain account to which it applies. When the entry is made in the Cash Journal, the number of the page on which it is recorded will be entered under Folio in the Record of Hedges. A separate page will be assigned in this record to each kind of grain hedged.

Record of Sales to Arrive.—A considerable number of elevators selling grain ''to arrive'' have no form on which to record such transactions. Form No. 6, (p. 51) is a record of sales made and terms of sale. The record of each sale will require one line on the left hand side of this form, though a sufficient number of lines will be left blank following each entry to allow the recording on the right-hand side of the cars shipped to fill the contract. This form is purely a memorandum form, but is important in keeping account of sales to arrive and deliveries made on such contracts. A separate page will be assigned to each kind of grain sold to arrive.

CASH JOURNAL AND PURCHASE AND SALES RECORD.

GENERAL CONSIDERATIONS.

Entries for all other transactions not properly falling into any of the classes previously discussed will be made in the Cash Journal and Purchase and Sales Record (Form No. 1, p. 48), which will hereafter be called the Cash Journal.

The transactions properly to be entered in the Cash Journal may be classified as those with (1) merchandise purchases and sales, (2) local personal accounts, (3) cash receipts and disbursements, and (4) sundry or general items. Before discussing these topics attention is called to some of the fundamental considerations involved in the plan of the Cash Journal.

It has been the usual practice to provide elevator systems with a cashbook, journal, and daybook under separate forms. In the system here described these books, together with a record of merchandise purchases and local retail sales, have been combined into one form.

This form differs from ordinary books of first entry in that both the debits and credits arising from transactions must of necessity be entered on it before it can be balanced.

The fundamental principle of double-entry bookkeeping is here illustrated; in every transaction two or more accounts are always affected and in opposite ways, these opposite effects being designated in accounting as debit and credit. That is, if value has been received or given it is necessary not only to show what account received, or cost value, but it is also necessary to show what account produced or surrendered that value. The debit and credit effects will be equal. For example, when merchandise is sold, the merchandise account obviously surrendered value, hence that account will be credited. In order to complete the entry, however, it is necessary to show what account or accounts have received an equivalent value, which in this case will be either the cash account or the accounts receivable account, which must be debited. Similarly, when a note with accrued interest is paid, the Cash account surrenders value equivalent to the sum of the note and interest, hence a credit to the Cash account. Again it is necessary to show what account or accounts have received, or cost value. In this case the Notes payable and the Interest accounts are involved. They will be debited respectively with the face value of the note and with the interest paid. Every transaction must be analyzed in a similar manner and an entry made showing the effect of the transaction on all accounts involved.

A column captioned Items is provided between the debit and the credit sides of the Cash Journal, in which are written the names of the ledger accounts to be debited or credited, and in each case an explanation of the transaction. Complete explanation must always be made in order that one unfamiliar with the transaction can understand it readily. The amount or amounts are then extended on the debit and credit sides under the proper headings. (See sample entries, p. 48.)

The debit columns, to the left of the Items column, are captioned, Date, Folio, Cash, Bank deposits, General ledger, Accounts receivable, Hard coal (lbs., amount), Soft coal (lbs., amount).

The credit columns, to the right of the Items column, are: Check number, Folio, Bank withdrawals, General ledger, Accounts receivable, Sales ticket number, Hard coal (lbs., amount), Soft coal (lbs., amount).

Blank columns are also provided on both sides to be used as desired.

MERCHANDISE PURCHASES.

Under the heading Merchandise purchases, on the debit side, are columns captioned: Hard coal, Soft coal, etc., with provision for entering both pounds and amounts. Purchases of merchandise of this character are entered in their proper columns and only the totals posted at the end of the month to the debit of their respective accounts in the general ledger. Expense items which contribute directly to the cost of a particular line of merchandise, as, for instance, freight on a car of hard coal, or labor for unloading it, should be entered under Hard coal. Such items constitute a part of the cost of the merchandise delivered at the elevator and should not be charged to expense. Where more lines of merchandise are carried than the number of columns provided, such purchases must be recorded in the General ledger column and posted to the debit of their respective ledger accounts in detail.

Each amount under Merchandise purchases will be balanced by an entry of a similar amount on the right hand page of the Cash Journal, either in the General ledger column, to the credit of the firm from which the purchase was made, or under Bank withdrawals, to the credit of the bank, depending upon whether the purchase was a time or cash transaction.

LOCAL SALES OF MERCHANDISE AND GRAIN.

Sales Ticket.—All sales of merchandise will be recorded on Sales Tickets (Form No. 13, p. 46) at the time of sale. These tickets are put up in pads and may be carried by the employee, so that it will not be necessary to go to the office after each sale to make the proper record. At convenient times the information on the Sales Tickets will be entered in the Cash Journal.

The number of each Sales Ticket will be listed in the Sales ticket number colunm, and the merchandise, in pounds and amount, will be entered in the proper column under Local sales on the credit side of the Cash Journal, i. e., Hard coal, Soft coal, Flour, etc.

Each sale of merchandise thus entered on the credit side must be balanced by an entry on the debit side, either under Cash or Accounts receivable, depending upon whether the transaction is a cash or charge sale.

Where the volume of the retail business is large, it is recommended that the Sales Tickets be recapitulated daily and an entry be made in the Cash Journal for the total of the sales. The debits to the Accounts Receivable Ledger will then be posted direct from the Sales Tickets.

The merchandise sales columns will be totaled at the end of the month and the totals posted to the credit of the proper accounts in the General Ledger.

Elevators which handle a greater number of side lines than the number of sales columns provided on this form may obtain a distribution sheet from the publishers, and the totals of this sheet will be entered each day in the Cash Journal.

ACCOUNTS RECEIVABLE.

A column captioned Accounts receivable, is provided on the debit side of the Cash Journal, in which are entered all debits to the personal accounts. At the end of the month the total of this column is posted to the debit of the Accounts receivable control account in the General Ledger, and the detail is posted to the debit of the personal accounts in the Accounts Receivable Ledger. In the Accounts receivable column on the credit side will be entered collections on local accounts. These items will be posted in detail to the credit of accounts in the Account Receivable Ledger, and the total of the column for the month will be posted to the credit of the Accounts receivable control account in the General Ledger.

CASH.

Cash Receipts.—In order to account properly for all currency received, the use of the Cash Receipt (Form No. 14, p. 47) is advised. These receipts may be filed conveniently until such time as they can be entered in the Cash Journal, which should be at least once each day.

In order that an accurate check may be maintained on the amount of money received, and an identical amount may be deposited each day, all cash receipts of whatever nature, as well as drafts drawn on commission companies, will be entered in the Cash column. The source of each item of cash thus received will be indicated by an entry of a similar amount, or several amounts aggregating this total, in the proper columns on the right-hand page. The entries in the Cash column are totaled before each deposit. All cash must be deposited before the books are posted at the end of the month.

Bank deposits.—In order that the deposits shown in the bank pass book may be verified readily, the actual amount of each deposit is entered in the Bank deposit column, the Cash column being ruled beneath the last item included in the deposit. The total of this column for the month is posted to the debit of the Bank account in the General Ledger.

Bank withdrawals.—The number of each check issued should be entered in the Check number column, and the amount in the Bank withdrawals column. The total of this column for the month will be posted to the credit of the Bank account in the General Ledger.

Each item of bank withdrawals will be balanced by an entry on the debit side of the Cash Journal either under Merchandise purchases or under General ledger, depending upon whether the disbursement was for a cash purchase of merchandise, payment of a note, an open account, or an expense item.

General ledger.—The General ledger columns are for entries of all items to be posted to accounts which appear in the General Ledger and for which no special columns are provided. The left-hand column accommodates the debits and the right-hand column the credits. Postings from these columns will be made in detail.

It will be noted that only the items which appear in the General ledger and Accounts receivable columns are posted in detail, all other columns, both debit and credit, being posted in total only.

REPORTS—GRAIN, MERCHANDISE, AND MANAGER'S.

The Grain Report (Form No. 8, p. 52) is designed to keep the manager and directorate in close touch with the condition of the grain stock and the hedges at the end of any month, or, in fact, at any time at which the entries on the various grain forms are footed.

On this report items 1, 6, and 11 are taken from the previous report, being the amounts shown thereon as Storage outstanding to-day, Total purchased to date, and Total sales to date. Items 2, 4, 7, 8, 12, and 13 are the footings, for the period, of the Record of Storage Tickets Issued, Record of Stored Grain Purchased, Record of Cash Grain Purchased, Record of Shipments and Sales, and the local sales of grain entered in the Cash Journal, respectively. Item 19, Undelivered sales, is the undelivered "sales to arrive" as shown by the Record of Sales to Arrive. Item 22, Proprietorship grain, is any grain on hand that has been purchased but not sold, plus any undelivered grain on growers' contracts. This item always represents the amount of grain to be hedged. Items 24 and 25 are taken from the Record of Hedges. By a comparison of item 24 with item 22, or item 25 with item 23, the manager and directors can tell at once whether the open option deals are legitimate hedging transactions. In case the elevator is fully protected, the amount of uncanceled futures sold should equal the proprietorship grain, and the uncanceled futures bought should equal the amount oversold, or the excess of sales over purchases. Owing to the fluctuations in the spread between contract grades and the lower grades, it is usually inadvisable to hedge the latter.

Item 26, Balance long, indicates the amount of unprotected grain and is ascertained by deducting item 24 from item 22 or item 23 from item 25. Item 27, Balance short, indicates illegitimate holdings of options and is ascertained by deducting item 22 from item 24 or item 25 from item 23.

In this report all grain in transit is considered as grain on hand. Therefore in determining the amount of insurable grain in the house, the grain in transit should be deducted from item 15, Grain in elevator.

This report is an essential part of the system; in that it furnishes the information necessary to the opportune selling, hedging, and insuring of grain.

The Merchandise Report (reverse side of Form No. 8) is a stock record, showing the total on hand at the time of the last inventory, the purchases, the sales, and the quantity on hand. This amount should agree very nearly with the physical inventory. By means of this report any shortage in stock will be discovered and the reasons therefor determined before serious loss results.

Manager's Report.—Where the business is not sufficient to warrant the hiring of a bookkeeper, or where the manager is unable to keep the books, it has been found convenient to secure the part-time services of a bookkeeper employed in some other enterprise. For such elevators a Manager's Report (Form No. 9, p. 53) is provided. This report may also be used by companies which operate several houses from a central office.

All Storage Tickets, Cash Grain Checks, and Stored Grain Checks are listed in detail in the spaces provided on this form. All checks other than grain checks are itemized in the lower left-hand corner. All drafts drawn on commission firms, together with checks received from commission firms, are itemized under Drafts drawn and checks received. Under this heading are recorded the name of the commission firm to be credited, the car number, and the amount of the draft or check.

Under Sales to Arrive should be entered all such sales, showing the company to whom the sale is made, the number of bushels, the kind and class of grain, the grade, price, and delivery date.

In the space headed Consignment shipments and deliveries on contract are recorded all cars shipped. In the column headed Applied on contract of will be entered the date of the contract in case the car is applied on a sale to arrive. Under Options memo are recorded all purchases and sales of futures. In the column headed P. or S. should be entered Purchased or Sold as the case may be.

Space is provided on the right-hand margin for a detailed explanation of all transactions not falling in any of the above classes.

LEDGERS.

Patronage Ledger (Form No. 7, p. 49), has been devised to provide a record of business done with each patron. This form will be used only by elevators operating under cooperative-organization laws which provide for the distribution of profits on a patronage basis. A page is assigned to each patron, and at convenient times during the year all Grain Checks and Sales Tickets will be recorded. This record facilitates the distribution of patronage dividends.

The *General Ledger* and *Accounts Receivable Ledger.*—Every transaction is entered in the Journal. By means of special columns in this book certain items of frequent recurrence are segregated at the time the original entries are made. The Journal, however, does not provide a complete segregation, since its chief function is to serve as a chronological record of transactions. It is therefore necessary to transcribe or "post" the Journal entries to the Ledger, where they are classified completely, all items of a similar nature being assembled in an account. The Ledger is divided for convenience into two sections, which are designated as the General Ledger and the Accounts Receivable Ledger. The latter contains only local personal accounts.

In posting from the Journal, only those items that appear in the General ledger and the Accounts receivable columns of the Cash Journal, and in the Net proceeds column of the Record of Shipments and Sales are posted in detail.

The monthly footings of all columns excepting those captioned General ledger in the Cash Journal, and Net proceeds in the Record of Grain Shipments and Sales are posted to the proper accounts in the General Ledger. The number of postings is thus greatly reduced.

CLASSIFICATION OF GENERAL LEDGER ACCOUNTS.

The following General Ledger accounts, with few exceptions, are believed to be adequate for any country elevator. It is obvious that all of the merchandise purchases and sales accounts will not be needed by every elevator, while on the other hand additional merchandise accounts will be needed by others. The operation of all accounts is shown in detail.

The accounts hereafter described are so arranged that a monthly Income and Expense statement can be constructed with little work and without the necessity of closing the books.

In opening the ledger accounts the sequence in which the accounts are given below should be adhered to, as this sequence will facilitate the making of income and expense statements and the posting.

The scheme of numbering the accounts used herein is recommended, as it allows the insertion of additional accounts without breaking the sequence.

In the discussions of ledger accounts which follow, the term "fiscal period" means the financial or other operating period as distinguished from the calendar periods. The term "at time of opening the books" means the time of installing a new system of accounts.

Balance Sheet Accounts (Nos. A–I, Inclusive).

ASSETS.

Account No.

A. Current Assets:
- A1. Cash on Hand.
- A2. Petty Cash.
- A3. Cash in Bank.
- A4. Notes Receivable.
- A5. Accounts Receivable Control.
- A6. Accounts Receivable (Grain Commission Account).
- A7. Grain and Merchandise Inventory.

B. Accrued Assets:
- B1. Accrued Interest—Notes Receivable.
- B2. Accrued Storage.

C. Fixed Assets:
- C1. Land.
- C2. Buildings.
- C3. Machinery and Equipment.
- C4. Office Furniture and Equipment.

D. Accounts Paid in Advance.
- D1. Prepaid Insurance.
- D2. Printing and Stationery Inventory.

E. Other Assets.
- E1. Railroad Claims.

LIABILITIES, RESERVES, AND NET WORTH.

Account No.

F. Current Liabilities:
- F1. Notes Payable.
- F2. Accounts Payable.
- F3. Stock Dividend Payable.
- F4 Patronage Dividend Payable.
- F5. Storage Liability.
- F6. Notes Receivable Discounted.

G. Accrued Liabilities:
- G1. Accrued Interest—Notes Payable.
- G2. Accrued Salaries and Labor.
- G3. Accrued Rent and Taxes.

H. Reserves:
- H1. Depreciation—Buildings.
- H2. Depreciation—Machinery and Equipment.
- H3. Depreciation—Office Furniture and Equipment.
- H4. Doubtful Accounts.
- H5. Sinking fund.

I. Net Worth.
- I1. Capital Stock.
- I2. Surplus.
- I3. Loss and Gain.

Income and Expense Accounts (Nos. J–N, Inclusive).

INCOME ACCOUNTS.

Account No.

J. Grain Accounts:
- J1. Wheat.
- J2. Oats.
- J3. Barley.
- J4. Rye.
- J5. Flax.
- J6. Corn.

K. Merchandise Accounts:
- K1. Flour.
- K2. Feed.
- K3. Coal.

L. Other Income Accounts.
- L1. Dockage Sales.
- L2. Grinding.
- L3. Cleaning.
- L4. Storage.
- L5. Discount Received.

EXPENSE ACCOUNTS.

Account No.

M. Operating Expense:
- M1. Salaries and Labor.
- M2. Heat, Light, and Power.
- M3. Repairs.
- M4. Depreciation—Plant.
- M5. Leakage in Transit.
- M6. Shrinkage and Scale Loss.
- M7. Express, Freight, and Drayage.

N. Administrative Expense:
- N1. Telephone, Telegraph, and Postage.
- N2. Printing, Stationery, and Office Supplies.
- N3. Interest.
- N4. Rent and Taxes.
- N5. Insurance.
- N6. Loss from Bad Accounts.
- N7. Miscellaneous

A. CURRENT ASSETS.

Cash on Hand (A1).

Debit:	Credit:
1. With the undeposited cash at the time of opening the books as shown by the Balance Sheet.	1. At the beginning of the month with an amount sufficient to close the account. The amount credited will, of course, be identical with that debited at the close of the previous month.
2. At the beginning of the fiscal period with the undeposited receipts carried over from the previous fiscal period.	
3. At the end of the month with the undeposited receipts.	

Petty Cash (A2).

Debit:	Credit:
1. With the amount of the fund originally created.	1. With the amounts transferred to the general fund when the petty cash fund is decreased or discontinued.
2. With the amount of the increase in case the fund is increased.	

It will be noted that all cash receipts are deposited in the bank, each bank deposit representing the exact amount of cash received since the previous deposit. Practically all elevators need some cash for the payment of small expense items and for making change. This need can be met most conveniently by the creation of a petty cash fund, which operates as follows: A check is drawn for the desired amount, say $20. This check is charged to the Petty Cash account in the ledger. All small expense items paid from this fund are entered in a Petty Cash book, any small notebook being used for this purpose. (See page 43.) When the fund needs replenishing, and always at the end of the month, these petty cash disbursements are recapitulated and a check is drawn for their total. An entry is then made in the Cash Journal, debiting the proper expense accounts and crediting the bank for the total paid out.

By following this system, the Petty Cash account always represents a resource of the original amount, unless changed, and all current receipts of cash can be deposited.

Cash in Bank (A3).

Debit:	Credit:
1. With the available balance of the cash in the bank as shown by the Balance Sheet at the time of opening the books.	1. With any overdraft as shown by the balance sheet at the time of opening the books.
2. With the total monthly deposits as shown by the Bank Deposits column in the Cash Journal. This will include checks, currency, drafts on consignees, as well as the proceeds of notes discounted.	2. With the monthly totals of checks drawn as shown by the Bank Withdrawals column in the Cash Journal and the Amount columns in the Record of Grain Purchases.

Items of exchange and interest should be entered at the time the bank statement is received. Such charges and credits will be indicated by charge and credit memoranda submitted by the bank with the paid checks and should be entered in the bank columns, debiting Miscellaneous Expense with exchange charges and debiting or crediting Interest account with interest items.

Notes Receivable (*A4*).

Debit:	Credit:
1. With the face value of the notes of others on hand as shown by the Balance Sheet at the time of opening the books.	1. With the amounts received in payment of notes held.
2. With the face value of new notes taken in payment of any debt owed to the company.	2. With the face value of notes receivable discounted when such notes are reported paid or are past due and no notice of default has been received from the bank. (Debit Notes Receivable Discounted.)
	3. With the face value of notes otherwise disposed of.

See Notes Receivable Discounted.

Accounts Receivable Control (*A5*).

Debit:	Credit:
1. With the total of accounts outstanding at the time of opening the books as shown by the Balance Sheet.	1. With the monthly totals of collections on account, as shown by the credit Accounts receivable column in the Cash Journal.
2. With the monthly totals of the charge sales as shown by the debit Accounts receivable column in the Cash Journal.	2. With any other credits to customer's accounts, including the writing off of uncollectible accounts. (See Reserve for Bad Debts.)

The debit balance of this account must equal the total of the outstanding accounts as shown by the Accounts Receivable Ledger.

Accounts Receivable (*Grain Commission Accounts*) (*A6*).

Debit:	Credit:
1. With the net proceeds as shown by the account sales rendered for each car sold.	1. With the drafts drawn against shipments.
2. With the interest due the elevator on balances, where grain firms allow such a charge. (Credit Interest account.)	2. With the checks received in full or partial settlement of account.
	3. With the interest charged on balances due commission firms.

Separate accounts should be opened with commission firms with which current business is transacted. Firms with which an irregular business is done may be assembled on one ledger page headed Miscellaneous Grain Firms.

Grain and Merchandise Inventory (*A7*).

Debit:	Credit:
1. With the value of merchandise and grain on hand as shown by the balance sheet at the time of opening the books. 2. With the value of grain and merchandise on hand and in transit at the end of the fiscal period. (Credit the various grain and merchandise accounts.)	1. With the amount necessary to close this account at the beginning of a new fiscal period. (Debit the various merchandise and grain accounts.)

This account is raised for the purpose of showing this asset on the books at the time of closing. It is closed into the various grain and merchandise accounts immediately upon reopening the books for the following fiscal period.

B. ACCRUED ASSETS.

Accrued Interest—Notes Receivable (*B1*).

(To be used only by the larger companies. See also Interest account, No. N3.)

Debit:	Credit:
1. With the accrued interest on Notes Receivable as shown by the balance sheet at the time of opening the books. 1. With the interest accrued on Notes Receivable during the period. (Credit Interest account.)	1. With interest received.

The balance of this account represents the accrued interest on notes receivable and should be shown as an asset on the Balance Sheet.

Accrued Storage (*B2*).

Debit:	Credit:
1. With the accrued storage as shown by the balance sheet at the time of opening the books. 2. With the accrued storage at the close of the period. (Credit Storage account.)	1. At the beginning of a new fiscal period with the amount previously debited to this account. (Debit Storage account.)

This account is raised to show on the books, at the time of closing, the earning from storage which has not yet been collected but which is an earning of the period.

C. FIXED ASSETS.

Land (*C1*).

Debit:	Credit:
1. With the cost of the land owned as shown by the Balance Sheet at the time of opening the books.	1. With the cost of any land sold.
2. With any subsequent purchases of land.	
3. With the cost of any permanent improvement, such as sewers, water mains, etc.	

If any land is sold at a price in excess of its cost, such excess should be credited to surplus.

In cases where a company installs a switch, the expenditure should be debited to an account appropriately captioned and its value depreciated annually in the same manner as the buildings.

Buildings (*C2*).

Debit:	Credit:
1. With the cost of the buildings as shown by the Balance Sheet at the time of opening the books.	1. With the total cost of any buildings sold or destroyed.
2. With the cost of all new constructions.	2. With the total cost of parts of buildings destroyed or replaced. (Debit Reserve for Depreciation on Buildings.)
3. With the cost of all additions or alterations when such cost increases the utility.	
4. With the cost of replacements.	

See discussion of extraordinary losses page 28.

See also Reserve for Depreciation on Buildings.

Machinery and Equipment (*C3*).

Debit:	Credit:
1. With the original cost of the machinery and equipment as shown by the Balance Sheet at the time of opening the books.	1. With the cost value of machinery or equipment sold, discarded, or destroyed, at which time debit Cash account for the amount realized, if any, and debit Reserve for Depreciation on Machinery and Equipment for the difference between the cost value and the amount realized.
2. With the cost of subsequent purchases of machinery and equipment, including freight or express on same, installation, etc.	
3. With the cost of alterations and improvements increasing the efficiency of the capacity of the plant.	

The balance of this account represents the cost of machinery and equipment in use.

See discussion of extraordinary losses, page 28.

Office Furniture and Equipment (*C4*).

Debit:	Credit:
1. With the original cost of office furniture and equipment as shown by the Balance Sheet at the time of opening the books. 2. With the cost of additional equipment purchased, including transportation, installation, etc.	1. With the cost of any item sold, discarded, or destroyed. (See credit under Machinery and Equipment.)

See discussion of extraordinary losses, page 28.

D. ACCOUNTS PAID IN ADVANCE.

Prepaid Insurance (*D1*).

Debit:	Credit:
1. With the amount of unexpired insurance premiums at the time of opening the books as shown by the Balance Sheet. 2. With insurance premiums paid. (Credit Bank account.)	1. At the close of a fiscal period with the insurance premiums expired during the period. (Debit Insurance Expense.) 2. With refunds on canceled policies.

The debit balance of this account is an asset and should be shown on the Balance Sheet.

Printing and Stationery—Inventory (*D2*).

Debit:	Credit:
1. With the value of unused printing and stationery on hand at the time of opening the books as shown by the Balance Sheet. 2. With purchases of printing and stationery.	1. At the end of the period with the amount consumed or discarded during the period. (Debit Printing, Stationery, and Office Supplies Expense.)

The balance of this account is an asset and should be shown on the Balance Sheet.

E. OTHER ASSETS.

Railroad Claims (*E1*).

Debit:	Credit:
1. With the valid claims at the time of opening the books as shown by the Balance Sheet. 2. With claims entered against transportation companies for loss due to leakage in transit. (Credit the Grain or Merchandise account concerned.)	1. With amounts collected on account of claims entered. (Debit Cash.) 2. With the net loss due to leakage in transit. (Debit Leakage in Transit account.)

In a large number of the instances where loss of grain results from leakage in transit the elevator company has a legimate claim against the transportation company. When a claim for such a loss is made, an entry should be passed crediting the grain account affected and debiting the Railroad Claims account. When cash is received in full or partial settlement of the claim, the Cash account will be debited and the Railroad Claims account credited with the amount collected. Any uncollectible claims will be debited to the Leakage in Transit account and credited to the Railroad Claims account. At the end of the year unsettled claims, on which it is believed recovery will be made, will be inventoried and carried to the following year.

Since claims carried over from one year to the next may prove to be worthless, it is suggested that a reserve account be set up to cover such possible losses rather than to carry the claims over from one year to the next as an absolute asset. Where an account, Reserve for Loss on Realization of Railroad Claims, is set up, it would be debited with losses on any claims carried over from one year to the next. Such a reserve would be created in the same manner as described under Loss from Bad Debts.

F. CURRENT LIABILITIES.

Notes Payable (*F1*).

Debit:	Credit:
1. With amounts paid on outstanding notes.	1. With the balance of outstanding notes at the time of opening the books as shown by the balance sheet.
2. With the unpaid portion of old notes canceled by renewal.	2. With all new notes issued, including renewals of old notes.

Accounts Payable (*F2*).

Debit:	Credit:
1. With payments on account.	1. With amounts due creditors on open accounts at the time of opening the books as shown by the balance sheet.
2. With purchased goods returned for credit.	2. With the invoice value of merchandise purchased on credit.
3. With allowances and refunds on purchases.	

Separate accounts should be opened for firms with which a credit business is conducted currently. Miscellaneous accounts payable may be handled in one account under the caption Miscellaneous Accounts Payable.

Stock Dividend (*F3*).

Debit:	Credit:
1. With the amount of the dividend when it is paid.	1. With the dividend declaration when such dividend is expressed as a percentage of the capital stock. (Debit Surplus.)

Dividends should be numbered and so earmarked in the items column of the ledger page.

Patronage Dividend (*F4*).

Debit:	Credit:
1. With the amount of the dividend when it is paid.	1. With the dividend declaration when such dividend is based on the amount of business transacted. (Debit Surplus.)

Storage Liability (*F5*).

Debit:	Credit:
1. At the beginning of a fiscal period the storage liability at the close of the previous fiscal period. (Credit Loss and Gain.)	1. With the market value of stored grain as shown by the balance sheet at the time of opening the books.
	2. With the inventory value of stored grain at the end of a fiscal period. (Debit Loss and Gain.)

In calculating the liability arising from storage tickets outstanding at the end of the year, the same price must be used as is used in computing the value of the inventory of grain on hand and in transit.

Notes Receivable Discounted (*F6*).

Debit:	Credit:
1. With the face value of notes receivable discounted which have been reported by the bank as having been paid by the signers. (The Notes Receivable account is credited at this time.)	1. With the face value of any notes receivable discounted held by the bank as shown by the balance sheet at the time of opening the books.
2. With any discounted note redeemed by the business. (In this case the Notes Receivable account is not affected as the note is still owned by the company.)	2. With the face value of all notes subsequently discounted. (Debit Interest account with the amount of the discount and Cash account with the proceeds.)

Notes received by the company, especially those received in payment for shares of stock, are frequently discounted at the bank. Such discounted notes represent a contingent liability, for if the makers refuse or are unable to pay, the company discounting them is liable to the bank for their payment. The credit balance of this account indicates the extent of this contingent liability. When all such notes are paid, the contingent liability will disappear from the books. Shares of stock for which notes are taken should be held as collateral to secure the payment of the notes. In case the note is past due and no notice of payment has been received, it may usually be taken for granted that the note has been paid.

G. ACCRUED LIABILITIES.

Accrued Interest—Notes Payable (G1).

(To be used only by the larger companies. See also Interest Account No. N-3.)

Debit:	Credit:
1. With interest payments.	1. With the accrued interest on notes payable at the time of opening the books as shown by the balance sheet. 2. With the interest accrued during the period on notes payable. (Debit Interest account.)

The balance of this account is the accrued interest on notes payable and should be shown as a liability on the balance sheet.

Accrued Salaries and Labor (G2).

Debit:	Credit:
1. With the credit balance at the beginning of the fiscal period. (Credit corresponding expense account.)	1. With the amount of unpaid labor at the time of opening the books as shown by the balance sheet. 2. With the amount of unpaid labor at the end of the fiscal period. (Debit corresponding expense account.)

In order that the Ledger may show the true conditions of the business at the end of the fiscal period, it is necessary that an account or accounts be opened which will exhibit the liability arising from items of expense which have accrued, but which have not yet become payable. Examples of such items are salaries and wages and taxes. These accruals necessarily constitute a portion of the costs of operation of the fiscal period just closed and therefore should be charged to the expenses for that period.

Accrued Rent and Taxes (G3).

Debit:	Credit:
1. At the beginning of the fiscal period with the credit balance. (Credit Rent and Taxes.)	1. With the amount of accrued rent and taxes at the time of opening the books as shown by the balance sheet. 2. With the amount of accrued rent and taxes at the end of the fiscal period. (Debit corresponding Expense account.)

H. RESERVES.

Reserve for Depreciation—Buildings (*H–1*).

Debit:	Credit:
1. With the cost value of entire buildings or parts of buildings discarded or destroyed. (Credit Buildings.)	1. With the amount reserved at the time of opening the books as shown by the balance sheet. 2. At the end of the fiscal period with the estimated amount of depreciation. (Debit Depreciation on Plant.)

Where an entire roof, floor, or other part of a building is renewed, the original cost of the renewed part should be charged to this account, and the cost of the renewal to the Buildings account.

See Extraordinary Losses, page 28.

Reserve for Depreciation—Machinery and Equipment (*H–2*).

Debit:	Credit:
1. With the cost value of machinery or equipment destroyed or discarded. (Credit Machinery and Equipment.) 2. With the difference between the cost value and amount realized from items sold. (Credit Machinery and Equipment.)	1. With the amount reserved at the time of opening the books as shown by the balance sheet. 2. With the estimated amount of depreciation at the end of the fiscal period. (Debit Depreciation on Plant.) 3. With any amounts realized on sales of machinery and equipment which have previously been charged to this account.

Reserve for Depreciation—Office Furniture and Equipment (*H–3*).

Debit:	Credit:
1. With the cost value of items destroyed or discarded. (Credit Office Furniture and Equipment.) 2. With the difference between cost and amount realized from items sold. (Credit Office Furniture and Equipment.)	1. With the amount reserved at the time of opening the books as shown by the balance sheet. 2. With the estimated amount of depreciation at the close of the fiscal period. (Debit Depreciation on Plant.) 3. With any amounts realized on sales of items which have previously been charged to this account.

See Extraordinary Losses, page 28.

Reserve for Doubtful Accounts (*H–4*).

Debit:	Credit:
1. With the amount of outstanding accounts found to be uncollectible. (Credit Accounts Receivable.)	1. With the amount reserved at the time of opening the books as shown by the balance sheet.
	2. With an amount estimated to cover the probable losses due to uncollectible accounts during the fiscal period. (Debit Loss from Bad Accounts.)

Any collections made on accounts which have previously been charged off as worthless should be credited to this account.

Reserve for Sinking Fund (*H–5*).

Debit:	Credit:
1. When funds are disbursed for the purpose for which the reserve has been created. (Credit Surplus.)	1. With the amount reserved at the time of opening the books as shown by the balance sheet.
	2. With the amount reserved during the fiscal period for any specific purpose. (Debit Surplus.)

In some States, notably South Dakota, where the cooperative law is in operation, statutory regulations requires that an amount equal to a certain percentage of the capital invested be set aside each year in a sinking fund, so that the company will be in a position to retire its capital stock at the end of a given period. Companies operating under such conditions should set up a reserve for sinking fund in accordance with the requirements of their State law.

A sinking fund may be established for expansion purposes or to pay off mortgages at their maturity. Amounts so reserved should be deposited in a special account and not used as working capital.

I. NET WORTH.

Capital Stock (*I–1*).

Debit:	Credit:
1. With the par value of shares of stock retired.	1. With the par value of shares of stock outstanding at the time of opening the books as shown by the balance sheet.
	2. With the par value of shares of stock issued subsequently.

The balance of this account should represent the value at par of all outstanding shares of stock. In case shares are retired at a cost above or below par, the difference will be debited or credited, as the case may be, to Surplus.

Surplus (I-2).

Debit:	Credit:
1. With the amount of dividends declared by the board of directors. (Credit Dividend account.)	1. With the amount of surplus at the time of opening the books as shown by the balance sheet.
2. With any net loss at the end of a fiscal period as shown by a debit balance of the Loss and Gain account. (Credit Loss and Gain.)	2. With the amount of net gain at the end of each fiscal period, as shown by a credit balance of the Loss and Gain account. (Debit Loss and Gain.)
3. With amounts reserved for Sinking Fund. (Credit Reserve for Sinking Fund.)	3. With amounts of sinking fund expenditures when such fund is disbursed. (Debit Reserve for Sinking Fund.)
4. With adjustments decreasing the profits of a previous fiscal period.[1]	4. With adjustments increasing the profits of a previous period.[1]

In case the liabilities and outstanding capital stock exceed the total assets at the time of opening the books, the entry to this account will be a debit and will indicate a deficit. The same will be true if, at any future time, this account has a debit balance.

Loss and Gain (I-3).

Debit:	Credit:
1. At the end of the fiscal year with any debit balances of income accounts (showing losses) and with the debit balances of the expense accounts.[3] (At this time credit such accounts.)	1. With the credit balances of all income accounts at the close of the fiscal period.[2] (Debit Income Accounts.)
2. With the storage liability at the end of the fiscal period. (Credit Storage Liability.)	2. At the beginning of the fiscal period with the storage liability at the close of the previous fiscal period. (Debit Storage Liability.)

At the end of the fiscal period, if the credits to this account exceed the debits, a net gain is shown; but if the debits exceed the credits, a net loss has resulted from the year's operations. This account will be closed by a debit or credit, as the case may be, to Surplus account.

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[1] Errors and omissions are often found which apply to a previous fiscal period. Adjustment of such items will be made through the Surplus account as indicated.

[2] See accounts under Income Accounts in the classification.

[3] See accounts under Expense Accounts in the classification.

J. GRAIN ACCOUNTS.

Wheat (*J1*).

Debit:

1. With the inventory carried over from the previous fiscal period as shown in the Inventory account at the time of opening the books and at the beginning of each fiscal period.
2. With the total cost of purchases as shown by the Record of Grain Purchases at the end of each month.
3. With the losses on hedging transactions. (Credit Commission accounts.)
4. With the credit balance at the end of the fiscal period. (Credit Loss and Gain.)

Credit:

1. With the total net proceeds from sales as shown by the Record of Grain Shipments and Sales, and the local sales column in the Cash Journal at the end of each month.
2. With the profits made on hedging transactions. (Debit Commission accounts.)
3. With claims filed for losses due to leakage in transit. (Debit Railroad Claims.)
4. With the inventory of wheat on hand and in transit at the end of the fiscal period. (Debit Inventory account.)
5. With any shortage due to shrinkage and scale loss at the end of the fiscal period. (Debit Shrinkage and Scale Loss.)
6. With any debit balance at the end of the fiscal period. (Debit Loss and Gain.)

Oats (*J2*).

(See account No. J1.)

Barley (*J3*).

(See account No. J1.)

Rye (*J4*).

(See account No. J1.)

Flax (*J5*).

(See account No. J1.)

Corn (*J6*).

(See account No. J1.)

K. MERCHANDISE ACCOUNTS.

It will be found, where there are returned sales of merchandise, that it will be much more satisfactory to open separate accounts for purchases and sales. Returned sales will then be charged to the sales accounts, and returned purchases will be credited to the purchase accounts. This procedure will greatly facilitate the work of preparing income tax returns and can be applied to the grain accounts with equal advantage.

Flour (K1).

Debit:	Credit:
1. With the inventory carried over from the previous fiscal period as shown by the Inventory account, at the time of opening the books and at the beginning of each fiscal period.	1. With the monthly sales as shown by the total of the flour sales column in the Cash Journal.
2. With the cost of goods purchased.	2. With goods purchased and subsequently returned for credit. (Debit Accounts Payable.)
3. With freight on purchased goods, extra labor for unloading, and other direct charges.	3. With the value of the inventory on hand at the end of the fiscal period. (Debit Inventory account.)
4. With goods which have been recorded as sold but which have subsequently been returned.	4. With any shortage in the physical inventory at the end of the fiscal period. (Debit Shrinkage and Scale Loss.)
5. With the credit balance at the end of the fiscal period. (Credit Loss and Gain.)	5. With any debit balance at the end of the fiscal period. (Debit Loss and Gain.)

A separate account should be opened for each kind of grain and principal line of merchandise handled. At the end of the fiscal period, by crediting these accounts with the inventories and shrinkage and scale loss, the gross profit or loss will be determined. Where the total credits exceed the total debits, a gross profit is shown and the account is closed by balancing it and crediting Loss and Gain. Where a loss is shown by a net debit the reverse entry should be made.

Feed (K2).

(See account No. K1.)

Coal (K3).

(See account No. K1).

L. OTHER INCOME ACCOUNTS.

Dockage sales (L1).

Debit:	Credit:
1. With the credit balance at the close of the fiscal period. (Credit Loss and Gain.)	1. With the amounts received from sales of dockage.

Grinding (L2).

Debit:	Credit:
1. With the credit balance at the close of the fiscal period. (Credit Loss and Gain.)	1. With the amounts received for grinding.

Cleaning (L3).

(See account No. L2.)

Storage (L4).

Debit:	Credit:
1. At the beginning of the fiscal period with the amount of accrued storage at the close of the previous period. (Credit accrued storage.)	1. Monthly with the total of the storage column on the Record of Grain Purchases.
2. At the close of the period with the credit balance. (Credit Loss and Gain.)	2. At the close of the fiscal period with the accrued storage on outstanding storage tickets.

Discount Received (L5).

(See account No. L2.)

EXPENSE ACCOUNTS.

M. OPERATING EXPENSE.

Salaries and Labor (M1).

Debit:	Credit:
1. With the amounts paid to employees.	1. At the beginning of the fiscal period with the accrued salaries and labor at the close of the previous fiscal period. (Debit Accrued Salaries and Labor.)
2. With the accrued labor at the close of the fiscal period. (Credit Accrued Salaries and Labor.)	2. With the debit balance at the close of the fiscal period. (Debit Loss and Gain.)

Heat, Light, and Power (M2).

Debit:	Credit:
1. With invoices paid.	1. With the debit balance at the close of the fiscal period. (Debit Loss and Gain.)

Repairs (M3).

Debit:	Credit:
1. With the cost of repairs and renewals which are necessary to maintain the efficiency of the plant but which do not add to its original value.	1. With the debit balance at the close of the fiscal period. (Debit Loss and Gain.)

This account takes care of such items as a broken window pane, a new plank in the approach, or a new cup. Where an entire piece of equipment is replaced, the old piece should be charged to reserve for depreciation and the new one charged to Machinery and Equipment, Buildings, or Office Furniture and Equipment, as explained under those accounts.

Depreciation—Plant (*M4*).

Debit:	Credit:
1. With the amounts reserved out of the profits of each fiscal period to cover loss from wear, tear, and obsolescence of office furniture and equipment, machinery and equipment, and buildings. (Credit the corresponding reserve accounts.)	1. With the debit balance at the close of the fiscal period. (Debit Loss and Gain.)

Extraordinary losses caused by lightning, fire, or explosion may exceed the amount reserved for depreciation. Only the portion of the reserve applicable to the damaged property should be charged to the reserve account. The remaining portion of the loss should be debited to an account appropriately captioned, i. e., Fire Loss. This account must be charged off to Loss and Gain during the ensuing years. This method of apportioning the loss over a number of years is justifiable since the business of the current year was not responsible for the extraordinary loss. In case insurance is collected on account of a loss the amount should be credited to the proper reserve accounts.

Leakage in Transit (*M5*).

Debit:	Credit:
1. With uncollectible claims. (Credit Railroad Claims.)	1. With the debit balance at the close of the fiscal period. (Debit Loss and Gain.)

This method of handling losses due to leakage in transit not only gives the proper grain account credit for the grain actually shipped, but it reveals the facts relative to a source of loss which is often neglected entirely or given only minor consideration.

Shrinkage and Scale Loss (*M6*).

Debit:	Credit:
1. With any shortage in the physical inventories of grain and merchandise at the end of the fiscal period. (Credit the grain and merchandise accounts concerned.)	1. With any excess of the physical over the book inventory. (Debit the grain and merchandise accounts concerned.)
	2. With the debit balance of the account at the end of the fiscal period. (This is the net loss due to shrinkage and scale loss.) (Debit Loss and Gain.)

The desirability of having the books show the facts relative to all sources of cost necessitates the opening of an account to which may be carried discrepancies between the book inventories and the actual physical inventories of the various kinds of grain and merchandise at the end of the year. Inasmuch as shrinkage and scale loss is an expense to the elevator, it is desirable that the extent of such expense be definitely known.

By following this procedure each grain and merchandise account will show the actual gross gain or loss arising from a full accounting of the total quantity of grain and merchandise received, and the Loss and Gain account will show all items entering into the cost of operating the enterprise. Inasmuch as both leakage in transit and shrinkage and scale loss are factors at least partially under managerial control, changes in policy may result when the actual facts relative to these factors are ascertained.

Express, Freight, and Drayage (*M7*).

Debit:	Credit:
1. With payments of bills rendered.	1. With the debit balance at the close of the fiscal period. (Debit Loss and Gain.)

N. ADMINISTRATION EXPENSE.

Telephone, Telegraph, and Postage (*N1*).

(See account No. M2.)

Printing, Stationery, and Office Supplies (*N2*).

Debit:	Credit:
1. With purchases of minor supplies. 2. At the close of the period with the consumption during the period of printing and stationery. (Credit Printing and Stationery Inventory.)	1. With the debit balance at the close of the fiscal period. (Debit Loss and Gain.)

Interest (*N3*).

(To be used only by larger companies.)

Debit:	Credit:
1. With the interest accrued during the period on notes payable. (Credit Interest Accrued on Notes Payable.) 2. With discount on notes receivable discounted.	1. With the interest accrued during the period on notes receivable. (Debit Accrued Interest on Notes Receivable.)

This account is closed at the end of the fiscal period by a debit or credit, as the case may be, to Loss and Gain.

In the smaller companies it is believed advisable to ignore accrued interest items. In such cases but one interest account would be raised in the ledger, which would be operated as follows:

Interest.

Debit:	Credit:
1. With interest payments.	1. With interest received.
2. With discount on notes receivable discounted.	

Close the account at the end of the fiscal period by a debit or credit, as the case may be, to Loss and Gain.

Rent and taxes (*N4*).

Debit:	Credit:
1. With the payments made on account of rent and taxes.	1. At the beginning of the fiscal period with the accrued rent and taxes at the close of the previous fiscal period. (Debit Accrued Rent and Taxes.)
2. With accrued rent and taxes at the close of the fiscal period. (Credit Accrued Rent and Taxes.)	2. With the debit balance at the end of the fiscal period. (Debit Loss and Gain.)

Insurance (*N5*).

Debit:	Credit:
1. At the close of the fiscal period with the insurance premiums expired during the period. (Credit Prepaid Insurance.)	1. With the debit balance at the close of the fiscal period. (Debit Loss and Gain.)

Loss from bad accounts (*N6*).

Debit:	Credit:
1. With the amounts reserved out of the profits to cover the probable loss from bad debts. (Credit Reserve for Bad Debts.)	1. With the debit balance at the close of the fiscal period. (Debit Loss and Gain.)

Miscellaneous (*N7*).

Debit:	Credit:
1. With expenses which are not chargeable to any of the foregoing accounts.	1. With the debit balance at the close of the fiscal period. (Debit Loss and Gain.)

The individual needs and the peculiar conditions surrounding elevators in different parts of the United States may require accounts in addition to those discussed herein. If this be the case accounts covering special requirements may be opened along the same general lines.

THE TRIAL BALANCE.

From the discussion of the Journal and the Ledger, it will be noted that all entries made in the Ledger originated in the Journal. Two points therefore must be kept constantly in mind, namely: (1) No entries are to be made direct to the Ledger, but must be posted from original entries in the Journal; (2) the equality of the debits and credits of each page of the various Journal forms must be proved before any figures are either carried forward or posted to the Ledger. It follows, then, that if the Journal pages are proved to be in balance and the entries are correctly posted, the Ledger also must balance. In order to prove whether or not the equality of the debits and credits has thus been maintained, a Trial Balance must be taken of the Ledger at the end of each month. A Trial Balance consists of a schedule of the open accounts in the General Ledger showing in one column the accumulated debits and in another column the accumulated credits of the respective accounts. The footings of the two columns must be equal. A stock form of Trial Balance book should be secured for the permanent preservation of the monthly Trial Balances.

At the close of each fiscal period it is necessary to "close the books" and to prepare a Balance Sheet and an Income and Expense Statement in order to ascertain the results of the period's operations and the financial position of the company.

CLOSING THE BOOKS.

By the expression "closing the books" is meant the process of balancing all income and expense accounts by transferring their balances to the Loss and Gain account. After this has been done, the only open accounts to be found in the Ledger are the balance-sheet accounts which represent the assets and liabilities of the company.

Preparatory to closing the books, it will be necessary to make the following schedules:

Grain on hand and in transit............	List by kind, class, grade, and price.
Merchandise.............................	List by kind, class, condition, and price.
Storage tickets outstanding..............	List by kind, class, grade, and price.
Accrued storage on stored grain...........	List by ticket number, date, bushels, and rate.
Accrued interest on notes receivable....	List by name of drawer, date, time to run, interest rate, and amount of note.

Insurance premiums unexpired at the end of the period	List by policy number, date, property covered, time, and amount of premium unexpired.
Unused stationery and printing	List by quantity, kind, and value.
Accrued salaries and wages	List by name, time, and wage rate.
Accrued rent and taxes	List by name, time, and rate.
Accrued interest on notes payable	List by name of payee, date, time to run, interest rate, amount of note.

Great care must be exercised in inventorying grain and merchandise, and the liability for stored grain as the value of the income and expense statement and the balance sheet depend upon the accuracy of the inventories. This work should always be conducted, or at least directly supervised, by a competent committee of the board of directors.

When the above schedules have been completed, and the extensions made and verified, the following Journal entries should be constructed:

Debit.	(1)	Credit.
000	Inventory account	
	Wheat account	000
	Oats account	000
	Barley account	000
	Rye account	000
	Flax account	000
	Corn account	000

To plan the inventories on the books as an asset. (This is a neeessary step in closing the various grain accounts.)

Debit.	(2)	Credits.
000	Inventory account	
	Flour account	000
	Fuel account	000
	Coal account	000

To place the inventories on the books as an asset.

Debit.	(3)	Credit.
000	Shrinkage and Scale Loss	
	Wheat	000
	Oats	000
	Barley	000
	Rye	000
	Flax	000
	Corn	000

To account for all the grain received into the elevator and to show this loss as an expense of operation.

Debit.	(4)	Credit.
000	Shrinkage and Scale Loss	
	Flour	000
	Feed	000
	Coal	000

To account for all the merchandise purchased and to show this loss as an expense of operation.

Debit.	(5)	Credit.
000	Loss and Gain	
	Storage Liability	000

To set up on the books the liability arising from outstanding storage tickets and to reflect its result in the net income.

Debit.	(6)	Credit.
000	Insurance Expense	
	Prepaid Insurance	000

To place in the expense account the amount of insurance consumed during the period, and to reduce the asset of prepaid insurance to its actual amount.

Debit.	(7)	Credit.
000	Printing, Stationery, and Office Supplies	
	Printing and Stationery Inventory	000

To show the expense for this item and to reduce the asset account to the actual value of supplies on hand.

Debit.	(8)	Credit.
000	Salaries and Wages	
	Accrued Salaries and Wages	000

To show the expense in the period in which it accrued and to set the amount up as a liability on the books.

Debit.	(9)	Credit.
000	Rent and Taxes	
	Accrued Rent and Taxes	000
	(See entry No. 8.)	

Debit.	(10)	Credit.
000	Interest	
	Accrued Interest on Notes Payable	000
	(See entry No. 8.)	

Debit.	(11)	Credit.
000	Depreciation—Plant	
	Reserve for Depreciation—Machinery	000
	Reserve for Depreciation—Buildings	000
	Reserve for Depreciation—Office Furniture and Equipment	000

To show the expense arising from depreciation on the books and to reserve an amount out of the year's income to cover it.

Debit.	(12)	Credit.
000	Loss from Bad Accounts	
	Reserve for Doubtful Accounts	000

To reserve out of the income of the period an amount estimated to cover the loss which will accrue from credits extending during the period.

Debit.	(13)	Credit.
000	Accrued Interest on Notes Receivable	
	Interest	000

To show the earning in the period in which it accrued, and to show the accrual on the books as an asset.

Debit.	(14)	Credit.
000	Accrued Storage	
	Storage Account	000

To show the asset on the books, and to place the earning from storage in the income for the fiscal period in which it accrued.

Debit.	(15)	Credit.
000	Wheat account	
000	Oats account	
000	Barley account	
000	Rye account	
000	Flax account	
000	Corn account	
	Loss and Gain	000

To close the grain accounts and to transfer the gross gain to the Loss and Gain account.

Debit.	(16)	Credit.
000	Flour	
000	Feed	
000	Coal	
	Loss and Gain	000

(See entry No. 15.)

Debit.	(17)	Credit.
000	Dockage Sales.	
000	Grinding.	
000	Cleaning.	
000	Storage.	
000	Discount Received.	
	Loss and Gain	000

To close the miscellaneous income accounts and to transfer their balances to the Loss and Gain account.

Debit.	(18)	Credit.
000	Loss and Gain.	
	Salaries and Labor.	000
	Heat, Light, and Power.	000
	Repairs.	000
	Depreciation—Plant.	000
	Leakage in Transit.	000
	Shrinkage and Scale Loss.	000
	Express, Freight, and Drayage.	000
	Telephone, Telegraph and Postage.	000
	Printing, Stationery, and Office Supplies.	000
	Interest.	000
	Rent and Taxes.	000
	Insurance.	000
	Loss from Bad Accounts.	000
	Miscellaneous.	000

To close the expense accounts into Loss and Gain.

The above Journal entries when posted to the Ledger will balance all Income and Expense accounts and leave only the Asset and Liability accounts open. At this point all the balanced accounts should be ruled with a double red line beneath the footings.

The credit balance of the Loss and Gain account represents the net profit for the year.

A Trial Balance should now be taken to prove that the equality of the debits and credits of the Ledger accounts has been maintained, after which we are ready to proceed with the Balance Sheet and Income and Expense Statements.

In compiling the Balance Sheet it is necessary only to refer to the Ledger accounts and draw off the balances shown in the Asset and Liability accounts, entering them as indicated on the form of Balance Sheet provided herewith. The purpose of the Balance Sheet is to set forth the financial position of the company at a given time.

It will be noted that while the reserves for depreciation and bad accounts are shown on the Ledger as a liability they appear on the Balance Sheet as a deduction from the assets.

BALANCE SHEET.

The investigations made by the Bureau of Markets have disclosed the fact that many country elevators have never made either an Income and Expense Statement or a Balance Sheet. The form of Balance Sheet which follows conforms with that suggested by the Federal Reserve Board and is recommended as a simple yet comprehensive exhibit of the financial position of the company.

BALANCE SHEET.

ASSETS.

Cash:
- Cash on hand
- Cash in bank

Notes and Accounts Receivable:
- Customers' notes on hand (not past due)
- Customers' notes discounted
- Customers' accounts (not past due)
- Grain commission accounts
- Customers' notes (past due)
- Customers' accounts (past due)

Total

Less—

Reserve for bad debts

Inventories:
- Wheat, bu., at
- Oats, bu., at
- Barley, bu., at
- Rye, bu., at
- Flax, bu., at
- Corn, bu., at
- Feed, lbs.
- Flour, lbs.
- Coal, lbs.

Securities:
- Notes given by officers or employees
- Bonds
- Accounts due from officers or employees

Accrued Assets:
- Accrued interest on notes receivable
- Accrued storage

Total current assets

LIABILITIES.

Unsecured Notes Payable:
- Notes given for merchandise
- Notes given bank
- Notes given commission firms
- Notes given officers or employees

Unsecured Accounts Payable:
- Accounts payable for purchases (not yet due)
- Accounts payable for purchases (past due)
- Accounts payable to officers or employees

Stock dividend declared

Surplus and undivided profits

Secured Liabilities:
- Notes receivable discounted
- Storage liability

Accrued Liabilities:
- Accrued interest on notes payable
- Accrued salaries and labor
- Accrued rent and taxes

Total current liabilities

Fixed Assets:
Land................
Buildings...........
Machinery and equipment............
Office furniture and equipment........

Less—
Reserves for depreciation..........

Total fixed assets.................

Accounts paid in advance:
Prepaid insurance....
Printing and stationery inventory.....

Other Assets:
Railroad claims.. ..
Less—
Reserve for loss on railroad claims...

Total assets...........

Fixed Liabilities:
Notes secured by mortgages..........

Reserves:
Reserve for sinking fund..............

NET WORTH.

Capital stock..........
Surplus and undivided profits..............

Less deficit..........

Total..................

INCOME AND EXPENSE STATEMENT.

The Income and Expense Statement is an itemized statement of the entries made to the Loss and Gain account, arranged in such a way as to set forth clearly the results of the operations of the periods involved.

The following form of Income and Expense Statement will be found convenient for exhibiting the operations of the elevator for either a monthly or a yearly period. Wherever possible a monthly statement of income and expense is advised.

In the past no standard form of Income and Expense Statement has been used; therefore, this form should fill a very definite need. By its use not only the stockholders and directors may follow the details of the business, but a ready comparison may be made between the costs of operation of various elevators.

In preparing this statement the amounts shown as sales and purchases should be net figures. That is, merchandise returned by the buyer should be deducted from the total sales, and merchandise returned by the company to the concern from whom it was purchased should be deducted from the total purchases. Profit on hedges should be added to sales and loss on hedges should be added to purchases in the respective grain accounts.

INCOME AND EXPENSE STATEMENT.

.... months ending .... 191...

	Quantity.	Amount.	Loss.	Gain.
Wheat:				
Sales				
Leakage in transit (claims)				
Inventory, end of period				
Total shipped and on hand				
Add: Shortage (shrinkage and scale loss)				
Total accounted for				
Inventory, beginning of period				
Purchases				
Stored grain sold (storage liability)				
Total to account for				
Gross gain (or loss) on wheat (A statement similar to the above will be necessary for each kind of grain handled.)				
Gross gain (or loss) on grain				
Feed:				
Sales				
Shrinkage				
Inventory, end of period				
Total accounted for				
Inventory, beginning of period				
Purchases				
Total to account for				
Gross gain (or loss) on feed (A statement similar to the above will be necessary for each kind of merchandise.)				
Gross gain (or loss) on merchandise				
Total gross gain (or loss)				
Operating expenses:				
Salaries and labor				
Heat, light, and power				
Repairs				
Depreciation-plant				
Leakage in transit				
Shrinkage and scale loss				
Express, freight, and drayage				
Total operating expenses				

Administrative expenses:			
Telephone, telegraph, and postage	....		
Printing, stationery, and office supplies	....		
Interest	....		
Rent and taxes	....		
Insurance	....		
Loss from bad accounts	....		
Miscellaneous	....		
Total administrative expense	....	....	
Total expense	....	....	....
Net operating profit (or loss)	....	....	....
Miscellaneous income:			
Dockage sales	....	....	....
Grinding	....	....	....
Cleaning grain	....	....	....
Storage	....	....	....
Discount received	....	....	....
Total net profit (or loss)	....	....	....

OPENING ENTRIES.

Upon completing the Income and Expense Statement, the books of the company should be reopened by the following journal entries:

Debit.	(1)	Credit.
000	Wheat account	
000	Oats account	
000	Barley account	
000	Rye account	
000	Flax account	
000	Corn account	
000	Flour account	
000	Feed account	
000	Coal account	
	Inventory account	000

To close the inventory account by transferring the inventories to the various merchandise accounts.

Debit.	(2)	Credit.
000	Accrued Rent and Taxes	
	Rent and Taxes	000

To close the liability account and to show the expense charged to the previous period as a credit to the period in which it is paid.

Debit.	(3)	Credit.
000	Accrued Salaries and Labor	
	Salaries and Labor	000
	(See entry No. 2.)	

Debit.	(4)	Credit.
000	Storage account	
	Accrued storage	000

To close the asset account and to charge the income account with the storage credited to income in the previous period.

COST ANALYSIS.

The Cost Analysis (Form No. 15, p. 47) has been provided to show the unit cost of handling grain and merchandise. The method of preparing the statement is as follows:

First, opposite Bushels of grain and value of coal and merchandise, should be entered in the column headed Grain the total bushels of grain handled; in the column headed Sales, coal, the total value of coal sales; and in the column headed Sales, other merchandise, the total value of such sales. Second, in the column headed Total, enter the totals of all expense accounts opposite the proper captions in the left-hand margin. Third, apportion the amounts, as judgment and the books indicate, over grain, coal, and merchandise. Some items will apply only to grain, while others may apply to all sales. Fourth, foot the columns entering the totals opposite Total cost of operation. Fifth, ascertain the per cent of total cost of operation by dividing the total costs of operation for grain, coal sales, and sales of other merchandise, by the total cost of operating the business, and enter the quotients in the spaces provided opposite "Per cent of total cost of operation." Sixth, ascertain the total unit cost of operation for grain by dividing the total cost of operation for grain by the total number of bushels handled. This will be expressed in terms of cents and mills. In finding the total unit cost of operation for coal and for other merchandise the same method will be followed, but the result will be expressed in terms of percentage.

BALANCING CASH WITH THE BANK.

To prove the correctness of the cash entries for the month, the following method will be found simple and adequate:

(1) Be sure that the Bank columns are correctly footed.

(2) Determine whether the Bank deposits column agrees with the bank pass book as to individual deposits.

(3) Sort the returned checks, arranging them consecutively by series. Compare the expense checks with the entries in the Bank withdrawals column of the Cash Journal and the grain checks with the entries in the Record of Grain Purchases, and ascertain which, if any, are missing. List the numbers and amounts of all outstanding (missing) checks for the next month's reference. Outstanding checks may be listed either on an adding-machine tape or by writing them into the cash book. The sum of the bank balance as shown by the Ledger account, plus the total of the outstanding checks, should equal the balance as reported by the bank. No error, however small, should be ignored in comparing the balance of the bank account in the Ledger with the balance shown on the bank statement.

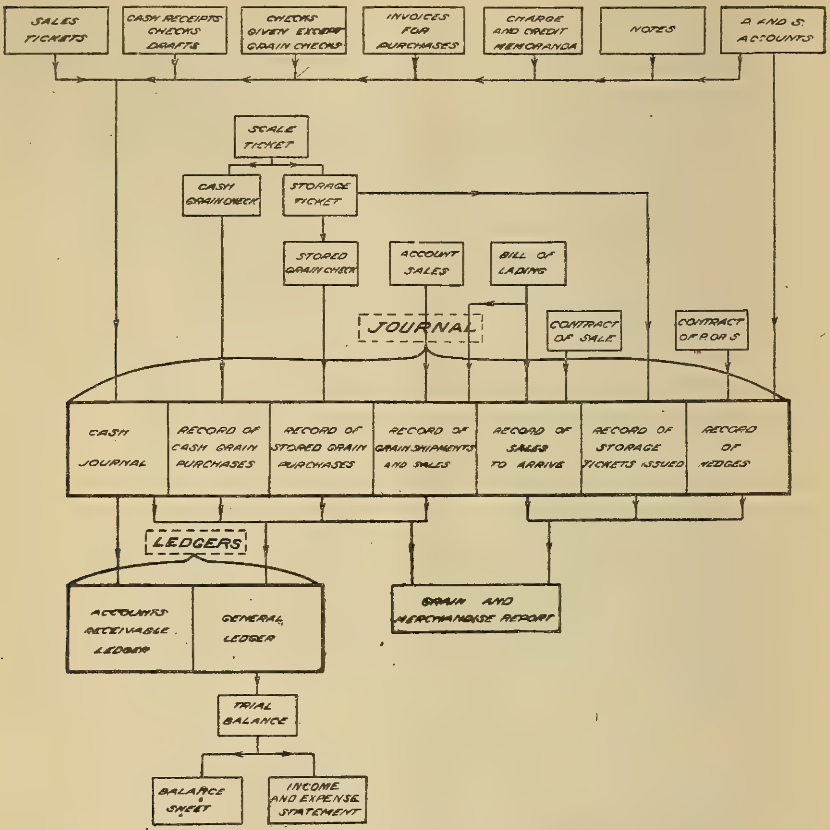
SUPPLY ACCOUNTS SETTLED WITH GRAIN.

When a request is received from a patron to deduct the amount which he may owe the company for supplies from the amount due him for grain sold, two grain checks should be issued. The first check should contain the total number of bushels and kind of grain being purchased, together with the balance due the patron after deducting the amount of his account from the full value of the grain. A second check should then be made without reference to bushels of grain and marked "for account receivable," in the full amount deducted from the previous check. This check is then indorsed by the patron and both checks are entered in the record of grain purchases, the first check going to the patron and the second being entered in the Cash Journal to the credit of the patron and deposited to the account of the elevator as cash received. By this means both sides of the transaction have been carried out through the only proper medium of settling accounts, which is cash.

CONCLUSION.

The foregoing pages describe the method of operating a system of grain elevator accounting devised to answer the requirements of grain elevators located at country points throughout the United States. The adoption of a uniform system of accounting should be of benefit both to the companies and to the men employed by them as managers, but the simple keeping of the records is not sufficient. To obtain benefits commensurable with the opportunities open in this field the manager and directors of the elevators possessing such an accounting system should make use of all the information which it is able to furnish. In order that the management of the elevator may be fully advised, not only as to the conditions of the business but as to the economic advantage of the present method of doing business, it is advisable that in every case careful attention should be paid to the grain and merchandise reports and to ascertaining the cost of operation by use of the Cost Analysis. If the information thus obtained is made available to the stockholders and other interested parties, and they are thus assured that the business of the elevator is being handled in a competent manner and that detailed information regarding it can be furnished at any time, it will tend to strengthen the financial position of the company with those who extend credit to elevators during the season of crop movements.

For the convenience of those interested in the system described in this bulletin, and for those who desire to install the system, the Bureau of Markets has provided printer's copy of the several forms for free distribution. A list of firms by whom the forms are published and carried in stock will be supplied on request. All elevators installing this system of accounts may refer to this bureau any question regarding its installation or operation.


SALES TICKETS
CASH RECEIPTS CHECKS DRAFTS
CHECKS GIVEN EXCEPT GRAIN CHECKS
INVOICES FOR PURCHASES
CHARGE AND CREDIT MEMORANDA
NOTES
A AND S ACCOUNTS
SCALE TICKET
CASH GRAIN CHECK
STORAGE TICKET
STORED GRAIN CHECK
ACCOUNT SALES
BILL OF LADING
JOURNAL
CONTRACT OF SALE
CONTRACT OF P OR S
CASH JOURNAL
RECORD OF CASH GRAIN PURCHASES
RECORD OF STORED GRAIN PURCHASES
RECORD OF GRAIN SHIPMENTS AND SALES
RECORD OF SALES TO ARRIVE
RECORD OF STORAGE TICKETS ISSUED
RECORD OF HEDGES
LEDGERS
ACCOUNTS RECEIVABLE LEDGER
GENERAL LEDGER
GRAIN AND MERCHANDISE REPORT
TRIAL BALANCE
BALANCE SHEET
INCOME AND EXPENSE STATEMENT

The general plan of the operation of the system as described herein is set forth in the diagram on this page. The source and progression of entries through the books are indicated by arrows.

In some of the forms that follow, sample entries are inserted in italics. These entries do not represent actual transactions; they are given merely to show how the forms are to be used.

The following is a convenient ruling for a petty cash book:

PETTY CASH BOOK.

Date.	Paid for—	Account charged.	Amount.	Check number.	Amount of cash.
July 1	*Drayage*	*Freight and drayage*	*$3.00*		
5	*Message*	*Telephone and telegraph*	*1.50*		
9	*Nails*	*Miscellaneous expense*	*.50*		
11	*Drayage*	*Freight and drayage*	*1.50*		
28	*Message*	*Telephone and telegraph*	*.50*		

RECAPITULATION.

July 31	*Freight and drayage*	*$4.50*		
	Miscellaneous expense	*.50*		
	Telephone and telegraph	*2.00*	*35*	*$7.00*
		7.00		

This check is in full payment of items listed below: No. ....

No.	Class.	Grade.	Gross.	Dkg.	Net.	Price.

To be made in duplicate.

CASH GRAIN CHECK. No. ....

FIRST NATIONAL BANK,

Blank, Minn., ..., 19...

Pay to the order of ....

.... $\frac{}{100}$ DOLLARS.

FARMERS ELEVATOR CO.,

By ....

Total value		
Deduction for		
Deduction for		
Amount of check.		

Bureau of Markets, Grain System Form No. 10A.

This check is in full payment of items listed below: No. ....

No.	Class.	Grade.	Gross.	Dkg.	Net.	Price.

STORED GRAIN CHECK. No. ....

FIRST NATIONAL BANK,

Blank, Minn., ..., 19...

Pay to the order of ....

.... $\frac{}{100}$ DOLLARS.

FARMERS ELEVATOR CO.,

By ....

Total value		
Deduction for storage		
Deduction for storage		
Amount of check.		

Bureau of Markets, Grain System Form No. 10B.

U. S. Department of Agriculture.
Bureau of Markets.
Grain System Form No. 11.

SCALE TICKET.

No. ...., *19*...

.... Co.

At ....

This ticket is not a storage ticket and is not negotiable. It must be exchanged on day of issue for a lawful storage ticket or cash check.

Owner..

Driver.................................. On .... Off............

Load of..

Grade. ....Dockage pounds...........

Signed..., Agent.

Exchanged for Check No. ...., Stores Ticket No. ....

Pounds.			Bushels.		
Gross.	Tare.	Net.	Gross.	Dockage.	Net.

No. ....

SALES TICKET.

Of..

At..

Sold to.............................. Date..........

HARD COAL.

Gross..	....	....
Tare..	....	....
Net..	....	....
Total hard coal............................	....	....

SOFT COAL.

Gross..	....	....
Tare..	....	....
Net..	....	....
Total soft coal............................	....	....

MISCELLANEOUS.

....	....	....
....	....	....
....	....	....
Total miscellaneous.........................	....	....
Total sales.................................	....	....

Bureau of Markets, Grain System.
Form No. 13.

U. S. Department of Agriculture.
Bureau of Markets.
Grain System Form No. 14.

No ....

CASH RECEIPT TICKET.

By..

Received from......................... Date........................., 19...

	Amount.

U. S. Department of Agriculture.
Bureau of Markets.
Grain System Form No. 15.

COST ANALYSIS.

.............................Elevator Company.............................

Year ending..........................., *19*....

	Total.	Grain.	Sales, coal.	Sales, other merchandise.
Bushels of grain and value of coal and merchandise				
Salaries				
Insurance				
Interest				
Power, operating				
Repairs				
Cooperage, cars				
Miscellaneous				
Bad debts				
Depreciation				
Shrinkage and scale loss				
Other losses and charges				
Total cost of operation				
Per cent of total cost of operation	100 per cent	.....per cent	.....per cent	.....per cent
Total unit cost of operation		.....per bu.	.....per cent	.....per cent

Storage Ticket No.	Gross.	Tare.	Net.
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

Bureau of Markets.
Grain System Form No. 12.

STORAGE TICKET

FARMERS' ELEVATOR COMPANY No..................

At......................................., 19....

Received of..

Bushels........................Grade........................Dockage................Grain................
which amount, kind, and grade of grain will be delivered to the holder of this receipt or his order upon surrender thereof, subject to the conditions and charges stated on the back of this receipt.

......................bu.,.........lbs. gross.

FARMERS' ELEVATOR COMPANY,

......................bu.,.........lbs. dockage.

......................bu.,.........lbs. net.

Per......................................

[Reverse.]

Below should be printed the rates of storage and the conditions affecting storage of grain as provided by laws in the State in which the elevator is situated.

Uni

ANSAI

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vabl

Lb

United States Department of Agriculture, Bureau of Markets,
Grain System Form No. 1.

CASH JOURNAL AND PURCHASE AND SALES RECORD.

Merchandise purchases.						Accounts receivable.	General ledger.		Bank deposits.	Cash	Folio.	Date.	Items.
		Soft coal		Hard coal.									
Lbs.	Amount.	Lbs.	Amount.	Lbs.	Amount.		Quantity.	Amount					
										45 00		1918. 11 1	Cash account (undeposited cash end of previous period)
						25 00							Geo. Black—on account
										150 00			Cash sales to-day
									195 00				Deposit
								25 00			1-c		Petty Cash account—established (check in favor of Nicholson)
		80,460	120 00									11 2	Illinois Coal Co. Car 68951
			80 00										Freight on above car
								12 50			3-b		Printing and stationery—Inventory (letterheads from Bruno & Co.)
						50 00							George Johnson—advance
										1,000 00		11 4	Lipsey & Co.—draft on car 1001
									1,000 00				Deposit
										10 00		11 8	George Black—received on account
										30 00			Cash sales to-day
									40 00				Deposit
								150 00			1-d	11 11	Notes Receivable
													John Doe (in payment of account)
										5 00		11 13	Prepaid Insurance (refund on canceled policy)
										450 00		11 15	Lipsey & Co. check—(balance on car 1001)
									455 00				Deposit
								2,000 00			6-a	11 18	Notes Payable
								20 00			14-b		Interest
													Check (for payment of our note and interest)
								18 50			10-a		Wheat account
													Dalrymple Grain Co. (loss on option)
		80,460	200 00			75 00		2,226 00	1,690 00				Footings forwarded

Items.	Check No.	Folio.	Bank withdrawals.	General Ledger.	Accounts receivable.	Sales ticket No.	Local sales of merchandise and grain.																	
							Hard coal.		Soft coal.		Feed.		Flour.		Wheat.									
							Lbs.	Amount.	Lbs.	Amount.	Lbs.	Amount.	Lbs.	Amount.	Lbs.	Amount.	Lbs.	Amount.	Lbs.	Amount.	Lbs.	Amount.	Lbs.	Amount.
Cash account (undeposited cash end of previous period)		1-a		45 00																				
Geo. Black—on account						51			4,000	25 00														
Cash sales to-day									2,000	13 00	4,000	100 00	300	35 00	60	2 00								
Deposit																								
Petty Cash account—established (check in favor of Nicholson)	80		25 00																					
Illinois Coal Co. Car 68951	81		120 00																					
Freight on above car	82		80 00																					
Printing and stationery—Inventory (letterheads from Bruno & Co.)	83		12 50																					
George Johnson—advance	84		50 00																					
Lipsey & Co.—draft on car 1001		1-f		1,000 00																				
Deposit																								
George Black—received on account					10 00																			
Cash sales to-day									2,000	13 00	500	12 50	75	4 50										
Deposit																								
Notes Receivable																								
John Doe (in payment of account)					100 00																			
Prepaid Insurance (refund on canceled policy)		3-a		5 00																				
Lipsey & Co. check—(balance on car 1001)		1-f		450 00																				
Deposit																								
Notes Payable																								
Interest																								
Check (for payment of our note and interest)	85		2,020 00																					
Wheat account																								
Dalrymple Grain Co. (loss on option)		1-f		18 50																				
Footings forwarded			2,307 50	1,518 50	110 00				8,000	51 00	4,500	112 50	375	39 50	60	2 00								

TORAGE TICKETS ISSUED.

	Oats.			Barley.				Mixed.							
						rade —		Grade —		Grade —		Grade —		Grade —	
T															

United States Department of Agriculture,
Bureau of Markets,
Grain System Form No. 2A.

RECORD OF STORAGE TICKETS ISSUED.

Date	Storage ticket No.	Paid by check No.	Wheat.																Oats.	Barley.	Rye.		Flax.		Corn.											
			Dockage—All wheat.	Spring—Hard red.				Winter—Hard red; soft red.				Durum.			Mixed.						Dockage.	Net.	Dockage.	Net.	White.				Yellow.				Mixed.			
				Grade 1	Grade 2	Grade 3	Grade —	Grade 1	Grade 2	Grade 3	Grade —	Grade 1	Grade 2	Grade —	Grade 1	Grade 2	Grade 3	Grade —							Grade —	Grade —	Grade —	Grade —	Grade —	Grade —	Grade —	Grade —	Grade —	Grade —	Grade —	Grade —
1918																																				
11	200		1 00	100 00																																
11	201		40		50 00																															
11	202																						2 00	100 00												
11 11	203		4 00	400 00																																
11	204																						1 30	75 00												
11 1	205		3 00	450 00																																
11	206																						4 00	725 00												
To be carried to Grain Report. Form 3-A.			8 40	950 00	50 00																		7 30	900 00												

134432°—18. (Face p. 48.) No. 2.

United States Department of Agriculture,
Bureau of Markets, Grain System, Form No. 3.

RECORD OF

Date.		Storage ticket No.	Check No.	Price.		Amount of check.		Storage charge.		Wheat											
										Gross all wheat.		Dockage all wheat.		Spring—Hard red.				Winter—Hard red, soft red.			
														Grade 1	Grade 2	Grade 3	Grade——	Grade 1	Grade 2	Grade 3	Grade——
11	1	98	1,051	2	00	995	00	5	00	505		5			500						
11	11	73	1,052	2	01	2,000	00	10	00	1,033	20	33	20		1,000						
11	12	74-78	1,053	3	50	3,141	00	9	00												
11	20	99	1,054	2	00	2,985	00	15	00	1,525		25			1,500						
*Total bushels																					
**Total amount						9,121	00	39	00	3,063	20	63	20		3,000						

134432°—19. (Face p. 48.) No. 3—1

* To be carried to Grain report.

** Cost column to be debited to grain accounts at end of month.

GRAIN PURCHASES.

Wheat.								Oats.		
Durum.			Mixed.				Cost all wheat.	Grade ——	Grade ——	Cost.
Grade 1	Grade 2	Grade ——	Grade 1	Grade 2	Grade 3	Grade ——				
							1,000 00			
							2,010 00			
							3,000 00			
							6,010 00			

134432°—19. (Face p. 48.) No. 3—2

United States Department of Agriculture,
Bureau of Markets, Grain System, Form No. 3-A.—Insert.

RECORD OF

Barley.		Rye.				Flax.			
Bushels.	Cost.	Gross.	Dockage	Net.	Cost.	Gross.	Dockage.	Net.	Cost.
						96,912	69 12	900	3,150 00
						96,912	69 12	900	3,150 00

			Mixed.								Cost all corn.		
	Grade —		le —		Grade —			Grade —					

134432°

GRAIN PURCHASES.

	Corn.												
	White.				Yellow.				Mixed.				Cost all corn.
	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	

184432°—19. (Face p. 48.) No. 3—4

United States Department of Agriculture, Bureau of Markets
Grain System, Form No. 4A.

RECORD OF GRAIN

Date.		Shipped to—	Car number and initial.	Shipper's grade.	Shipper's weight.		Date sold.		Price.		Net proceeds.		Folio	Wheat.											
														Gross, all wheat.		Dockage, all wheat.		Spring, hard red.							
																		Grade 1.		Grade 2.		Grade 3.		Grade —.	
11	4	Lipsey & Co.	NP 1001	3 white	1,611		10	30		98	1,450	00	1-f												
11	5	" "	G N 19572	No. 2 spring.	1,456		11	20	2	11	3,050	00	1-f	1,455	30					1,455	30				
11	8	" "	G N 2734	No. 3 spring.	1,213		11	19	2	08	2,411	71	1-f	1,200		13						1,187			
11	9	" "	NP 70654	No. 1 spring.	1,370	30	11	20	2	13	2,811	69	1-f	1,370	30	13				1,357	30				
11	11	Haukinson & Co.	CG W 47931	3 white	1,400		11	19		80	1,076	00	1-f												
11	11	" "	NP 57946	Flax	1,660		11	22	3	75	5,480	00	1-f												
11	12	Lipsey & Co.	NP 87906	3 white	1,480		10	30		92	1,308	60	1-f												
11	13	" "	N W 75333	3 white	1,680		11	25		85	1,378	00	1-f												
11	13	" "	UR 49678	3 white	1,598		11	25		85	1,298	00	1-f												
11	18	Haukinson & Co.	G N 25078	Flax	1,560		11	29	3	63	5,469	60	1-f												
11	25	Lipsey & Co.	G N 24738	3 white	1,320		Forwarded to December.																		
		Total bushels (to be carried to Grain Report Form No 8-A.)																							
		Total amounts (proceeds to be posted to Credit of Grain Accounts)									25,733	30		4,026		20				2,812	60	1,187			

SHIPMENTS AND SALES.

Wheat.										
Winter—Hard red, soft red.				Durum.			Mixed.			
Grade 1.	Grade 2.	Grade 3.	Grade ——	Grade 1.	Grade 2.	Grade ——	Grade 1.	Grade 2.	Grade 3.	Grade ——

United States Department of Agriculture, Bureau of Markets
Grain System, Form No. 4A—Insert.

RECORD OF GRAIN

Proceeds, all wheat.		Oats.						Barley.		Rye.				Flax.		
		Grade ——		Grade ——		Proceeds.		Bushels.	Proceeds.	Gross.	Dockage.	Net.	Proceeds.	Gross.	Dockage.	Net.
		1,611	06			1,450	00									
3,050	00															
2,411	71															
2,811	59															
		1,398	30			1,076	00									
														1,550	50	1,500
		1,480				1,308	50									
		1,680				1,378	00									
		1,598				1,298	00									
														1,560	60	1,500
8,273	30	7,768	56			6,510	50							3,110	110	3,000

SHIPMENTS AND SALES.

	Flax.		Corn.												
	Proceeds.		White.				Yellow.				Mixed.				Proceeds, all corn.
			Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	Grade ——	
	5,480	00													
	5,469	60													
	10,949	60													

PATRONAGE LEDGER.

Bureau of Markets Grain System Form No.7.

Name:

Rate, — per bu.
Rate, — per cent.

Sales.									Purchases.						
Check No.	Wheat.	Durum.	Barley.	Oats.	Rye.	Flax.	Corn.	Cattle value.	Sales No.	Hard coal.	Soft coal.	Flour.	Grain.		

RECORD OF HEDGES.

WHEAT.

United States Department of Agriculture, Bureau of Markets, Grain System Form No. 5.

Futures bought.								P. & S. Accounts.				Futures sold.								Remarks.
Date.		Bushels.	Market.	Bought from—	Month.	Kind.	Price.	Dr.		Cr.	Folio.	Date.		Bushels.	Market.	Sold to—	Month.	Kind.	Price.	
11	*29*	*2,000*	*Mpls.*	*Dalrymple.*	*Dec.*	*2 Sp.*	*2.11*	*18*	*50*		*C-J 2.*	*10*	*1*	*3,000*	*Mpls.*	*Dalrymple.*	*Dec.*	*2 Sp.*	*2.10*	*Cr. Dalrymple.*
												11	*6*	*2,000*	"	"				

Open options to be carried to Grain Report Form No. 8-A.
Profits and losses on closed transactions to be carried to Cash Journal Form 1.

RECORD OF SALES TO ARRIVE.

OATS.

United States Department of Agriculture, Bureau of Markets, Grain System Form No. 6.

Date.		Bushels.		Kind.	Grade.	Price.	Delivery date.		Sold to—	Cars applied.	Shipper's weight.		Date shipped.		Date received.		Destination grade.	Destination weight.		Remarks.
10	30	3,000	. .	Oats...	3 W...	92	11	30	Lipsey & Co.....	NP 1001....	1,611	....	11	4	11	13	3 W...	1,611	06	
										NP 87906....	1,480	....	11	12	11	18	3 W...	1,480	....	

Undelivered sales to be carried to Grain Report Form No. 8–A.

GRAIN REPORT.

United States Department of Agriculture, Bureau of Markets, Grain System Form No. 8A.

For period November 1, 1918, to November 30, 1918, inclusive.

	Items.	Wheat.				Oats.		Barley.	Rye.	Flax.	Corn.		
		Spring.	Winter.	Durum.	Mixed.						White.	Yellow.	Mixed.
1	Storage outstanding previous report	5,000								2,000			
2	Storage this period	1,000								900			
3	Total	6,000								2,900			
4	Stored grain purchased this period	3,000								900			
5	Storage outstanding to-day	3,000								2,000			
6	Total purchased previous report	50,000				46,000				8,000			
7	Stored grain purchased this period	3,000								900			
8	Cash grain purchased this period	8,000				10,000				500			
9	Total purchased to date (received)	61,000				56,000				9,400			
10	Total receipts to date (9+5)	64,000				56,000				11,400			
11	Total sales previous report	42,000				30,000				8,000			
12	Total shipped this period	4,000				7,768	04			3,000			
13	Local sales this period	100				1,231	28						
14	Total sales to date (delivered)	46,100				39,000				11,000			
15	Grain in elevator (10–14)	17,900				17,000				400			
16	Purchased grain on hand (9–14)	14,900				17,000							
17	Undelivered growers' contracts	5,000				8,000							
18	Total	19,900				25,000							
19	Undelivered sales	10,000											

20	Stored grain shipped (14–9)								1,600			
21	Total	10,000							1,600			
22	Proprietorship grain (18–21) (or)	9,900				25,000						
23	Over sold (21–18)								1,600			
	LONG AND SHORT RECORD.											
24	Open option sales	10,000										
25	Open option purchases								1,500			
26	Balance long (25–23) or (22–24)					25,000						
27	Balance short (23–25) or (24–22)	100							100			

MERCHANDISE REPORT.

Items.												
On hand previous report												
Purchased this period												
Total												
Sales this period												
On hand to-day												
Physical inventory												

Reverse side of Form No. 8–A.

U. S. Departm
Bureau
Grain Syste

Station........ Date.................................., 19.... Report No. ....

St

Date.	Ticket No.	l, class, grade.	Gross.	Dkg.	Net.

Use this space for all information regarding the making or receiving of notes and for explanation of all other transactions.

Drafts drawn and checks received.

Commission accounts.

Firm.	Car No.	Amount.

Date.	Check No.	Kind.

Consignment shipments and deliveries on contract.

Date.	Consignee.	Car No.	Kind, class, and grade.	Gross Bu.	Applied on cont. of.

Sales Ticket No sales Nos. .... to.......... P. and S. Accounts Nos. .... to........

13443

U. S. Department of Agriculture,
Bureau of Markets,
Grain System Form. No. 9.

MANAGER'S REPORT.

Station................................ Manager................................ Date................................, 19.... Report No. ....

Storage tickets issued.					Cash grain purchases.								Stored grain purchases.									
Date.	Ticket No.	Kind, class, and grade.	Dkg.	Net.	Date.	Check No.	Price.	Amount.	Kind, class, and grade	Gross.	Dkg.	Net.	Date.	Check No.	Ticket No.	Price.	Amount.	Storage charge.	Kind, class, and grade.	Gross.	Dkg.	Net.

Use this space for all information regarding the making or receiving of notes and for explanation of all other transactions.

Drafts drawn and checks received.

Commission accounts.

Firm.	Car No.	Amount.

Checks other than grain checks.					Sales to arrive.						
Date.	Check No.	In favor of.	For.	Amount.	Date.	Sold to.	Bu.	Kind and class.	Grade.	Price.	Del date.

Options memo.							Consignment shipments and deliveries on contract.					
Date.	P. or S.	Bu.	Market.	Through.	Month.	Kind.	Date.	Consignee.	Car No.	Kind, class, and grade.	Gross Bu.	Applied on cont. of.

This report includes

Sales Ticket Nos. .... to .... Cash Receipts Nos. .... to .... Deposit Slips Nos. .... to .... Invoices for merchandise bought Nos. .... to .... Account sales Nos. .... to........ P. and S. Accounts Nos. .... to.........

134432°—19. (Follow p. 53.)

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 812

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. **PROFESSIONAL PAPER.** **May 31, 1920**

THE CLOVER AND ALFALFA SEED CHALCIS-FLY.[1]

By Theodore D. Urbahns,
Entomological Assistant, Cereal and Forage Insect Investigations.

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INTRODUCTION.

The chalcis-fly *Bruchophagus funebris* How. belongs to a group or superfamily of Hymenoptera known as Chalcidoidea. The habits of this species differ considerably from the general habits common to most of the other members of this group. Many of the Chalcidoidea are parasitic Hymenoptera, feeding, in the larval stage, upon various forms of insect life. *B. funebris*, on the other hand, is strictly phytophagous, and feeds within the growing seeds of alfalfa and red clover. This insect has for many years been a pest of clover seed throughout the Middle Western States, and has become generally known as the clover-seed chalcis-fly. The increased production of alfalfa seed throughout the Western States was followed by the rapid development of this insect in nearly all of the alfalfa seed-growing districts of the United States, so that at the present time it is the most destructive pest of alfalfa seed. The injury done is known to many farmers as "blighted seed," but this insect is now becoming more generally known among alfalfa-seed growers as the alfalfa-seed chalcis-fly.

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[1] In the summer of 1912 the writer was detailed to make a study of the alfalfa-seed chalcis-fly (*Bruchophagus funebris* How.), and different phases of these investigations have been continued up to the present time, most of them being conducted in the seed districts of California, Arizona, and Utah. The author's studies of the distribution of this insect and its parasites have been greatly assisted through the kindness of various members of the branch of Cereal and Forage Insect Investigations, and by Mr. Roland McKee, of the Office of Forage Crop Investigations, Bureau of Plant Industry. Special credit is due Messrs. R. N. Wilson, C. N. Ainslie, V. L. Wildermuth, E. G. Kelly, T. H. Parks, and H. T. Osborn, who made many personal field observations in connection with the life-history studies of this insect. The writer is also greatly indebted to Mr. A. B. Gahan for his kindness in making determinations of several new parasites of *B. funebris*.

HISTORY AND SYNONYMY.

This species was described by Dr. L. O. Howard[1] as *Eurytoma funebris.* It was for some years supposed to be a parasite of the clover-flower midge, *Dasyneura laguminicola* Lintner. The original description is as follows:

> *Male.*—Length of body 1.7^{mm}, expanse of wings 2.5^{mm}. Head slightly wider than thorax; antennæ nearly as long as thorax; flagellum of antennæ 6-jointed (counting the club as 1 joint); joints very strongly incised from above, subequal in length except club and first joint; each joint, except club, with two whorls of yellowish hair, each whorl as long as the joint. Top of head and thorax coarsely punctured, and covered with sparse and very short whitish hair. Subcostal vein yellowish and strong, reaches costa a little before the middle of the wing, and almost immediately gives off stigma; stigma with a small club and faint indication of a branch. Peduncle very strong and not long; abdomen very small, less than half the length of the thorax. General color black, eyes dark brown, knees, anterior tibiæ, all tarsi light brown.
>
> *Female.*—Length of body 1.9^{mm}, expanse of wings 2.7^{mm}. Antennæ shorter than in ♂ and joints much more closely united; no hairs; flagellum 7-jointed, the club larger in proportion than in the ♂. Abdomen longer than thorax, not pedunculated; ovipositor slightly extruded, light brown in color.

In 1894 Dr. W. H. Ashmead (2) referred this species to the genus Bruchophagus, supposing it to be a parasite of the seed weevils (Bruchidae).

Dr. A. D. Hopkins reared specimens from heads of crimson clover in 1896, at first supposing them to be parasites of the clover-seed midge, since they had been referred to as such in early literature. But upon careful examination of the infested seeds he found that *B. funebris* was feeding on the seeds. Dr. Hopkins (3) wrote as follows:

> Upon close examination to find their host insect, I was thoroughly surprised to find that it was not a parasite of an insect, but that it bred in the seed, and that scarcely a seed could be found in the bag that had not been a host of one of the interesting little creatures.

Dr. Hopkins (4) again mentions this insect:

> Additional evidence obtained from a study of all stages of this insect, together with some observations on its habits, seems to leave no doubt that this interesting little Chalcidid is a destructive enemy of the seed of crimson and common red clover. I also determined that it passes the winter in the seed left in the open field, evidently in the larval stage.

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[1] Figures in parentheses refer to "Literature cited," p. 20.

DISTRIBUTION.

In 1904 Dr. E. G. Titus (5) gave the following distribution of *B. funebris* by States: Hanford, Cal.; Fort Collins, Colo.; Marengo and Urbana, Ill.; Winona Lake, Ind.; Richmond, Kans.; Agricultural College, Mich.; Agricultural College, Miss.; St. Anthony Park, Minn.; Quaker Street, N. Y.; Corvallis, Oreg.; Providence, R. I.; Burlington, Vt.; Pullman, Wash.; Danville and Virginia Beach, Va., and the District of Columbia. Mr. George I. Reeves reported this species from Lincoln, Nebr., the same year, and in 1915 Prof. F. M. Webster reported its presence at Tyngsboro, Mass., Kensington, Md., Lebanon, N. H., and Chambersburg, Pa. It was further reported from Wakeman, Ohio, in 1905, by W. B. Hall; at Albuquerque, N. Mex., 1908, Sacaton, Ariz., 1909, and central Utah, 1910, by C. N. Ainslie; at Plano, Tex., in 1909, by T. D. Urbahns; at Twin Falls, Idaho, in 1911, by H. T. Osborn; at Nashville, Tenn., in 1910, by George G. Ainslie; at Newell, S. Dak., in 1913, by C. N. Ainslie; at Alva, Okla., in 1913, by E. G. Kelly; at Charleston, Mo., in 1914, by G. W. Barber; at Minden, Iowa, in 1915, by T. D. Urbahns; at Hagerstown, Md., in 1916, by H. L. Parker; and at Fallon, Nev., in 1917, by T. D. Urbahns.

Under later dates, *B. funebris* was reared from many additional localities by the writer and other persons connected with the Bureau of Entomology, so that at the present time it is known to be present in practically every locality in the United States where either red clover or alfalfa seed is grown to any extent.

In 1913 the writer found it in alfalfa seed reported by a seed dealer to have arrived from Germany. This species has also been reported from other foreign countries as follows:

1906, N. E. Hansen, *Medicago falcata,* Omsk, Siberia.
1907, C. V. Piper, alfalfa, Turkestan, Asia.
1908, Mr. Brand, alfalfa, Pisa and Matilla, Chile.
1908, N. E. Hansen, alfalfa, Tashkent, Turkestan, Asia.
1908, J. G. Sanders, alfalfa, Tashkent, Turkestan, Asia.
1910, C. P. Lounsbury, alfalfa, Cape Town, South Africa.

CHARACTER OF ATTACK.

The injury caused by the chalcis-fly consists entirely of the hollowing out of the developing seeds (Pl. II, fig. 2). By the time the alfalfa seed pods and the clover heads have matured the destructive work of this minute larva has been completed within the infested seed, and the result is a hollow seed containing the insect in one of its stages, or simply the seed shell from which the adult insect has emerged. (Pl. II, figs. 3 and 4.) This pest in no way interferes with the growing of either alfalfa or red clover for forage purposes, except in so far as a very poor stand may be expected when infested and hollowed-out seeds are planted. The loss caused by this pest is to the growing of alfalfa or clover for a seed crop, and the insect may therefore be considered strictly a seed pest.

FOOD PLANTS.

The following plants have been found to be food plants of the chalcis-fly, *B. funebris*, seeds of each of these having been found infested by this species:

Alfalfa (*Medicago sativa*).
Red clover (*Trifolium pratense*).
Bur clover (*Medicago hispida nigra*).
Bur clover (*Medicago hispida terebellum*).
Bur clover (*Medicago hispida denticulata*).
Medicago falcata.
Medicago ruthemia.
Medicago tunetana.
Medicago tuberculata.
Medicago arabica.

The seeds of the following list of closely related plants apparently are not attacked by the chalcis-fly:

White clover (*Trifolium repens*).
Alsike clover (*Trifolium hybridum*).
Yellow sweet clover (*Melilotus officinalis*).
White sweet clover (*Melilotus alba*).
Sour clover (*Melilotus indica*).

ECONOMIC IMPORTANCE.

Table I shows the destruction of alfalfa and clover seed as found in samples of seed taken in the given localities.

TABLE I.—*Percentage of alfalfa and red clover seed found infested by Bruchophagus funebris.*

Locality.	Date of collection.	Seeds examined.		Seed destroyed.	Remarks.
		Total.	Infested.		
				Per cent.	
Aberdeen, Idaho	Sept. 19, 1914	886	7	0.7	Alfalfa seed.
Do	do	902	45	5	Do.
Albany, Oreg.	Sept. 5, 1914	156	81	52	Red clover seed.
Bard, Calif.	May 7, 1915	1,374	723	52.6	Alfalfa seed.
Do	May 12, 1915	1,000	361	36.1	Do.
Do	May 20, 1915	1,100	260	23.6	Do.
Do	May 28, 1915	1,053	222	21	Do.
Do	June 8, 1915	1,236	400	32.3	Do.
Do	June 17, 1915	1,091	291	26.5	Do.
Do	June 23, 1915	1,005	268	26.6	Do.
Do	July 2, 1915	1,115	315	28.2	Do.
Do	do	1,228	311	25.3	Do.
Do	July 28, 1915	1,255	672	54.4	Do.
Do	Aug. 4, 1915	1,364	489	36	Do.
Do	do	1,125	245	21.7	Do.
Do	Aug. 8, 1915	1,028	533	48.1	Do.
Do	do	1,157	330	28	Do.
Do	Oct. 12, 1915	872	747	85	Do.
Bishop, Calif.	Nov. 10, 1914	691	212	30.7	Do.
Buckeye, Ariz.	Sept. 2, 1912	263	217	82	Do.
Burley, Idaho	Sept. 11, 1914	1,307	50	3.8	Do.
Caldwell, Idaho	Sept. 10, 1914	866	237	27.3	Do.
Chico, Calif.	Apr. 12, 1912	3,007	1,761	58.5	Do.
Do	Oct. 25, 1914	263	83	31	Do.
Chino, Calif.	Sept. 24, 1912	574	195	34	Do.

TABLE I.—*Percentage of alfalfa and red clover seed found infested by Bruchophagus funebris*—Continued.

Locality.	Date of collection.	Seeds examined.		Seed destroyed.	Remarks.
		Total.	Infested.		
				Per cent.	
Columbus, Ohio	Oct. 17, 1908	559	50	8.9	Red clover.[1]
Corcoran, Calif.	Oct. 3, 1912	317	118	37	Alfalfa seed.
Dos Palos, Calif.	Sept. 15, 1913	993	264	26.5	Do.
Glendale, Calif.	Aug. 26, 1912	311	32	12	Do.
Do.	Jan. 12, 1914	603	145	24	Do.
Gunnison, Utah	Sept. 23, 1914	816	34	4	Do.
Do.	do.	876	105	12	Do.
Do.	do.	835	59	7	Do.
Do.	do.	297	11	3.7	Do.
Do.	do.	591	35	5.9	Do.
Logan, Utah	Dec. 28, 1915	1,527	680	44.5	Do.[2]
Manti, Utah	Sept. 23, 1914	1,097	92	8.4	Do.
Mesilla Park, N. Mex.	Aug. 30, 1908	561	130	30.5	Do.[3]
Do.	do.	531	170	47.1	Do.
Murrietta, Calif.	Aug. 7, 1915	1,140	177	15.6	Do.
Myton, Utah	Apr. 5, 1912	1,000	395	39.5	Do.[4]
Nephi, Utah	Sept. 24, 1914	994	35	3.5	Do.
Do.	do.	845	119	13.5	Do.
Do.	do.	700	131	18.5	Do.
Do.	do.	1,046	19	1.8	Do.
Do.	do.	935	23	2.4	Do.
Pendleton, Oreg.	Sept. 9, 1914	764	229	30	Do.
Red Bluff, Calif.	Sept. 3, 1914	966	147	15.2	Do.
Riverside, Calif.		492	109	22	Do.
St. Anthony, Idaho	Sept. 17, 1914	629	23	3.6	Do.
Salt Lake City, Utah	May —, 1910	100	37	37	Do.[3]
Do.	do.	400	149	62.8	Do.[3]
Do.	do.	500	186	37.2	Do.[3]
Do.	Oct. 17, 1910	500	286	57	Do.[3]
Do.	Nov. 22, 1910	107	77	72	Do.[3]
Do.	Sept. 20, 1911	450	5	1	Clover.[4]
Do.	Jan. 16, 1914	1,387	52	3.7	Alfalfa seed.
Somerton, Ariz.	May 10, 1915	1,235	664	53.8	Do.
Tempe, Ariz.	June 28, 1912	167			Do.[5]
Do.	July 1, 1912	348			Do.[5]
Do.	July 8, 1912	670	237	35.4	Do.
Do.	July 15, 1912	684	403	50	Do.
Do.	Aug. 10, 1912	301	235	78	Do.
Do.	Oct. 29, 1912	321	134	42	Do.
Do.	July 22, 1913	899	412	46	Do.
Do.	do.	2,270	778	35	Do.
Do.	Aug. 20, 1913	939	439	47	Do.
Do.	July 24, 1914	1,445	408	28	Do.
Do.	Aug. 15, 1914	1,185	212	18	Do.
Twin Falls, Idaho	Sept. 14, 1914	1,117	322	29	Do.
Tulare, Calif.	Oct. 1, 1912	600	154	25.5	Do.
Do.	Nov. 18, 1913	655	243	37.5	Do.
Washington, D. C.	Oct. 20, 1910	361	96	26	Clover.[1]
Wellington, Kans.	June 3, 1910	400	333	83	Alfalfa seed.[6]
Do.	June 6, 1910	600	480	80	Do.
Woodland, Calif.	Sept. 2, 1914	558	98	18.	Do.
Yuma, Ariz.	Aug. 6, 1913	1,143	109	9.5	Do.
Do.	Aug. 7, 1913	833	277	24.4	Do.
Do.	do.	2,174	524	24	Do.
Do.	Oct. —, 1913	915	646	72.5	Do.
Do.	Dec. 19, 1913	484	443	91	Do.
Do.	Dec. 22, 1913	1,377	1,017	74	Do.
Do.	June 18, 1914	335	76	22.7	Do.
Do.	do.	1,076	171	16	Do.
Do.	do.	391	82	21	Do.
Do.	do.	585	24	4.2	Do.
Do.	do.	554	95	17	Do.
Do.	Apr. 24, 1915	706	277	39.2	Do.
Do.	June 11, 1915	1,047	311	29.5	Do.
Do.	July 21, 1915	1,295	214	16.5	Do.
Do.	do.	1,106	211	19.1	Do.

[1] Note made by T. H. Parks.
[2] Note made by E. L. Barrett.
[3] Note made by C. N. Ainslie.
[4] Note made by H. T. Osborn.
[5] Note made by R. N. Wilson.
[6] Note made by E. G. Kelly.

The loss to the alfalfa-seed crop depends upon the total yield and upon the percentage of infestation.

This loss frequently varies from 50 to 400 pounds per acre as a result of the destructive work of this pest. At an average price of 12 cents per pound the loss may then be estimated at from $6 to $48 per acre annually. While this loss in the aggregate is enormous, there is frequently an additional loss which is caused by the planting of uncleaned seed, resulting in a poor stand and the loss of time and money in replanting.

COMMON NAMES.

Bruchophagus funebris is commonly known throughout the Eastern States as the clover-seed chalcis-fly. Throughout the alfalfa seed-growing districts, which are located almost entirely in the Western States, this insect is better known as the alfalfa-seed chalcis fly. Many farmers, however, frequently refer to its destructive work as that of a seed weevil, while others simply refer to the injured seed as "blighted seed," and apparently are not familiar with the cause of this condition.

MEANS OF DISPERSION.

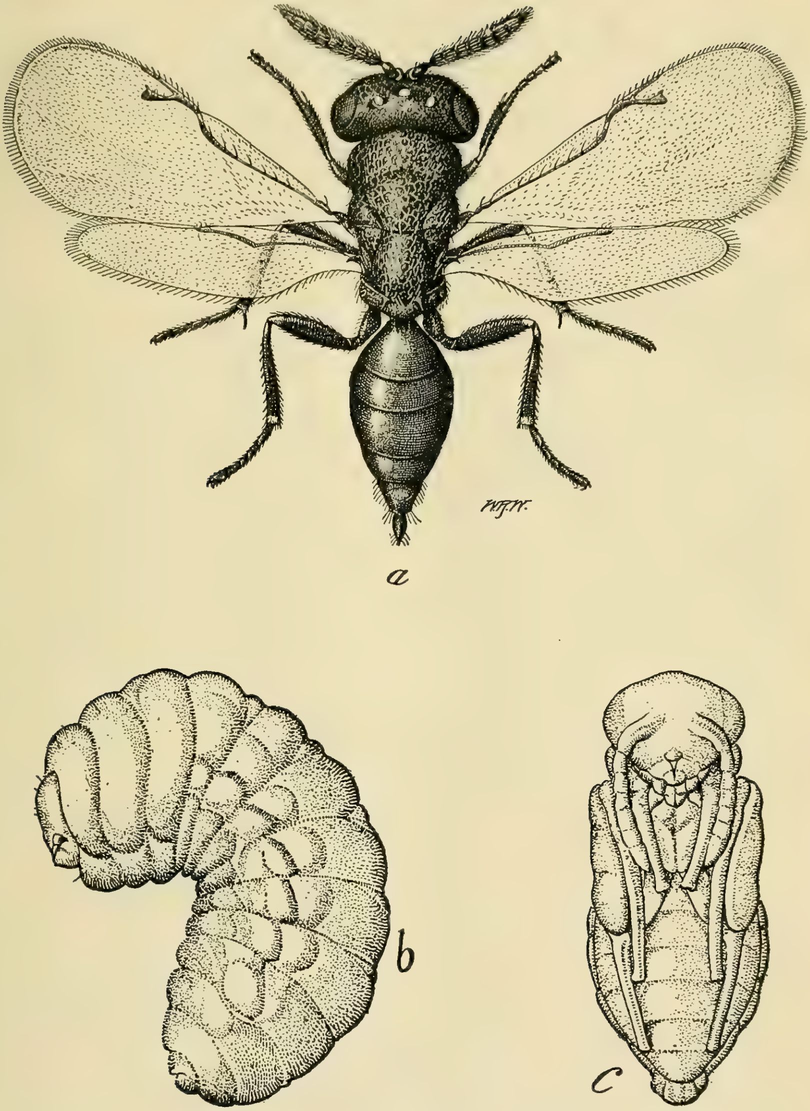
At the present time it is impossible to study in detail the means by which *B. funebris* became distributed over the different parts of the United States, for the reason that it is now found in almost every locality where either alfalfa or red-clover seeds are grown to any extent. It is, in fact, very probable that this species is a native of this country.

The shipment of infested seed from one locality to another has, without doubt, been a great factor in the dispersion of the alfalfa-seed chalcis-fly, since one can visit seed houses and frequently find hundreds of the adults present in the sacks of either clover or alfalfa seed.

Their spread probably was greatly aided also by the early settlers, who traveled across the country with horses and wagons, taking with them either clover or alfalfa hay bearing a few infested seed pods.

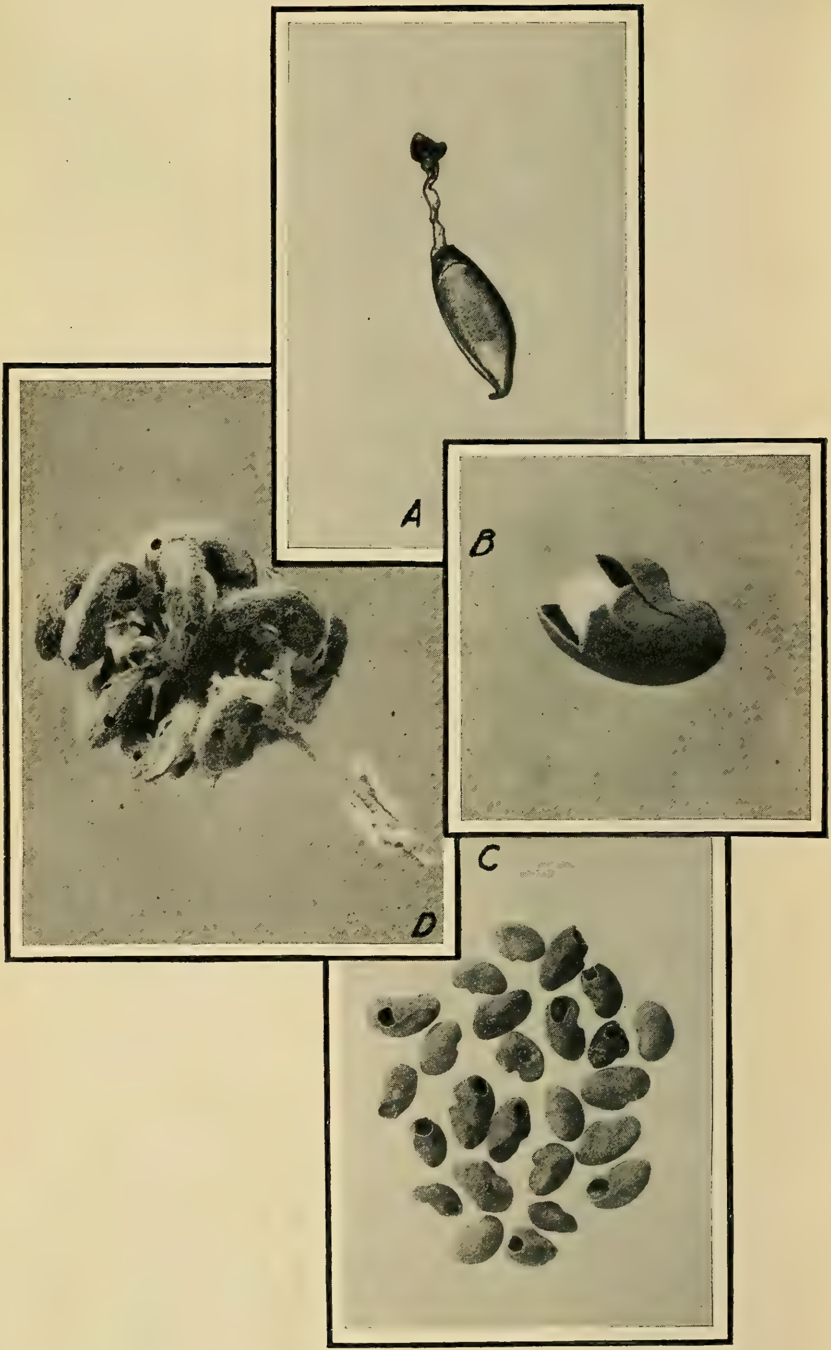
Throughout the mountain States there frequently is found a chain of small alfalfa patches along the mountain streams connecting the larger irrigation valleys, where alfalfa plants, along the edges of these fields, develop seed pods, and render conditions favorable for the spread of this insect from one field to another. Infested seeds and pods are undoubtedly washed down the mountain streams, enter irrigation canals, and may become distributed with the water over new fields many miles away.

The wind is an important factor in the dispersion of the adults of *B. funebris* over adjoining fields. The writer has frequently observed large numbers of chalcis-flies being carried by the strong summer breeze from one field to another. On one occasion more than



THE CLOVER AND ALFALFA SEED CHALCIS-FLY (BRUCHOPHAGUS FUNEBRIS).

a, Adult; *b*, larva; *c*, pupa.



The Clover and Alfalfa Seed Chalcis-Fly.

A, Egg; B, larva in hollow seed; C, cluster of seed pods showing openings from which adults emerged; D, seeds hollowed by *Bruchophagus funebris.*

two hundred adults of *B. funebris*, carried by the wind from a near-by field, alighted upon the writer's shirt in the course of a few minutes. Further observations revealed thousands of these chalcis-flies being carried by the winds.

LIFE HISTORY.

METHOD OF STUDY.

The life history of this seed chalcis-fly was studied by selecting old alfalfa plants and first carefully removing all seed pods which had begun to develop. The fresh blossoms were then artificially pollenized and covered with thin cheesecloth bags. About one week later the bags were removed and a mica breeding cage was placed over the soft green seed pods. One or more adults of *B. funebris* were then placed in the cage for oviposition into the green seeds. The mica cage, with the adults of *B. funebris*, was usually removed after one day, and the seed pods were again covered with cheesecloth bags. Here they were allowed to remain until desired for dissection and study of the various stages of the chalcis-fly, or until the first adults emerged. It was found that larvæ of *B. funebris*, which had been removed from their natural cavities in the infested seed, could be transferred to a cavity made in a small cork, and if properly covered with a medical capsule, or a small glass vial, they could be reared to the adult stage without difficulty in the laboratory. The hibernating larvæ and pupæ also were carried successfully through to the adult stage in cavities made between two layers of sheet cork.

Examinations of matured seeds were made by soaking the seeds for a few hours and then dissecting them under a binocular microscope.

The period of incubation was studied by allowing adults to oviposit into seed pods covered with mica cages and then dissecting some of the seed from day to day until the first eggs were found to have hatched.

THE EGG.

The egg (Pl. II, A) of *B. funebris* is small, elongated, measuring about 0.2 mm. long and 0.08 mm. in thickness. It consists of a delicate membranous bag filled with a semiliquid substance. One end of the egg is terminated in a flexible point, while the opposite end is marked by a slender tube-like film measuring about 0.2 mm. in length.

LARVA.

The larva (Pl. I, B) is grublike in shape. It averages 1.9 mm. long and 0.9 mm. wide when fully developed. The pointed brown mandibles are chitinous and visible to the unaided eye. With the exception of the mandibles the larva is white. It has no feet or legs and is almost free from pubescence. The 13 body segments are at times quite prominent.

PUPA.

The pupa (Pl. I, C) measures 1.8 mm. long. It is at first white, later the eyes and ocelli are brown, and before becoming adult the pupa turns black. All appendages are folded close to the body, and a thin pupal skin covers the insect in this stage of its development.

ADULT.

The adult (Pl. I, A) of *B. funebris* is a very small black insect measuring about 2 mm. in length. Frequently thousands are seen flying over the horses and mower when the alfalfa seed crop is being harvested. They also collect in great swarms on the shady sides of alfalfa seed stacks, from which these insects emerge. Farmers frequently mistake the adults of this species for gnats, which are about the same size and are frequently very troublesome at the time when the chalcis-fly is most abundant.

SEASONAL HISTORY.

EARLY DEVELOPMENT.

The first development of the chalcis-fly may be found in February and March throughout the Southwest, when the hibernating larvæ begin to transform to the pupal stage. Spring temperatures and moisture conditions determine the time of this transformation. In colder climates it is much later, and under desert conditions the larval stage may be prolonged indefinitely.

FIRST APPEARANCE OF ADULTS.

The first adults appear in the spring, about four or five weeks after warm weather has set in. It is probable that in southern California adults may be active in small numbers throughout the entire winter. Adults of *B. funebris* were taken in the fields in the San Fernando Valley, Calif., as early as March 3, but they usually do not appear in large numbers until about April. At Yuma, Ariz., they make their appearance in March, and the first seed pods, which usually develop along the check ridges, become infested by the middle of April. On April 17 green pods were taken at the edge of a field at Yuma, and upon careful examination, 8 seeds showed very small larvæ, 5 showed half-grown larvæ, 15 showed full-grown larvæ, and 20 showed *B. funebris* pupæ. E. G. Kelly observed adults of *B. funebris* in the field at Wellington, Kans., as early as April 21. H. T. Osborn reared them in out-of-door breeding cages in the same locality as early as April 17. In the valleys of central California the adults of *B. funebris* become active in April and oviposit into the seed pods of bur clover (*Medicago hispida*), which forms seed pods much earlier than alfalfa.

Mr. Kelly reported adults of *B. funebris* active and ovipositing in alfalfa seed pods at Wellington, Kans., by June 10, 1911.

OVIPOSITION.

The adults of *Bruchophagus funebris* appearing in early spring are not always able to locate developing seeds of their host plants at the time of their emergence, and it may be three or four weeks before an opportunity for oviposition is found. In midsummer oviposition takes place within a few days after the adult emerges. Green and half-grown seed pods are favored for oviposition. The female adult takes a position directly over the slight enlargement on the pod caused by the developing seed. The ovipositor is forced through the green seed pod and into the soft watery seed, where the egg is placed. The time required for oviposition is about one minute.

POSITION OF EGG.

The egg is usually placed just beneath the inner integument of the seed, sometimes between the cotyledons, and frequently within the semiliquid contents of a cotyledon. It is placed singly, although oviposition into the same seed may be repeated. The mark left by oviposition may sometimes be seen in the form of a very minute spot on the surface of the seed, but this is usually not discernible even with the aid of a microscope. The relative position of the seeds in a pod in no way seems to influence the chances of infestation.

EGG STAGE.

Observations made during the month of April at Pasadena, Calif., showed the period of incubation as requiring from 7 to 12 days. In the month of June the incubation period was found to be about five days. E. L. Barrett, assisting the writer, found eggs of *B. funebris* hatching in four days during very warm weather.

LARVAL STAGE.

The larva, upon hatching from the egg, finds itself surrounded with the soft contents of the growing seed. The first feeding takes place after the larva is one or two days old, and in midsummer rapid growth follows. The larva of *B. funebris* never leaves the seed in which it is developing to infest another seed in the same pod. Where two or more larvæ chance to be in the same seed, one or both usually perish before development is completed. Molts, apparently, occur indefinitely in the larval stage, and appear to be the peeling off, in small fragments, of the old larval skin. The time required for the complete development of the larval stage varies under differing temperature conditions, and depends upon the condition of the seed in which it develops. Under the most favorable conditions, as observed by the writer, the larvæ completed development in 12 days. In early spring this period was prolonged to 30 days.

PERIOD OF AESTIVATION.

The factors of greatest influence in the life cycle of *B. funebris* are those which determine the period of aestivation. Larvæ of this species, reaching their full larval development in soft green seeds, at once transform to the pupal stage and soon emerge as adults. On the other hand, if the infested seeds mature and harden before the larval development is fully completed aestivation follows. This resting period frequently continues throughout the remainder of the season, or until conditions become favorable for pupation and transformation to the adult stage.

Atmospheric humidity, temperature, and irrigation are important factors determining the duration of aestivation. Aestivation occurs frequently in the larvæ of *B. funebris* during the months of July, August, and September. Favorable conditions may at any time cause transformation to the pupal stage or aestivation may continue into hibernation. The transformation usually occurs at any time between March and July of the following season, though in exceptional cases the larval stage may be continued into the second year.

Alfalfa seeds collected in the fields on September 24, 1912, and kept dry in the laboratory showed adults of *B. funebris* emerging throughout the season of 1913 and larvæ living in the seeds until the spring of 1914. The last adults of *B. funebris* emerged as late as September, 1914. This habit causes great diffusion in the adults of the species. It was found that some of the progeny of a single adult developed and reached maturity in about 30 days, while other progeny from the same adult and from eggs deposited on the same day did not mature until the next year.

PUPATION.

The period of pupation in early spring requires an average of about 30 days, as shown by Table II. As the season advances and the days become warmer the duration of the pupal period is much shortened. Pupæ developing in midsummer have a pupal period of from 6 to 10 days, and under the most favorable conditions this period is without doubt shorter than that observed in the breeding cages.

LATE APPEARANCE OF ADULTS.

While some of the larvæ apparently go into hibernation as early as August, adults may be seen emerging from the infested seeds and seed pods in the months of October and November.

At Glendale, Calif., adults were still active in the fields as late as November 18, in 1912. C. N. Ainslie reported *B. funebris* as being numerous among the florets of red clover on September 17, in 1913, at Fairmont, Minn. At Albany, Oreg., the writer found them active over red clover on September 15, in 1914. At Nephi, Utah, they were active on alfalfa florets on September 24 of the same year. Activity of the adults, oviposition, and development of larvæ usually continue as long as green seed pods are present in the fields. The first heavy frost kills the adults and pupæ and most of the undeveloped larvæ.

The writer's observations show that in southwestern Arizona this species may have as many as four generations in a single season. This is, of course, under favorable conditions—first on volunteer alfalfa and then in the irrigated seed fields. Without doubt it completes at least two generations in most of the intermountain seed-growing districts, where the growing seasons are frequently very short. The minimum number of generations in a single season may be less than one under very unfavorable conditions, as it required more than one season for some of the individuals under observation to reach the adult stage.

TABLE II.—*Length of the pupal period for 50 individuals of Bruchophagus funebris which hibernated in the larval stage.*

Pupal period of male.	Days.	Pupal period of female.	Days.
Mar. 10 to Apr. 14	35	Mar. 10 to Apr. 22	43
Mar. 11 to Apr. 22	42	Mar. 10 to Apr. 14	35
Mar. 10 to Apr. 21	42	Mar. 11 to Apr. 14	34
Feb. 19 to Apr. 12	52	Mar. 10 to Apr. 22	43
Mar. 10 to Apr. 22	33	Mar. 11 to Apr. 22	42
Mar. 14 to Apr. 6	23	Mar. 11 to Apr. 21	41
Mar. 17 to Apr. 16	30	Mar. 20 to Apr. 28	39
Mar. 11 to Apr. 2	22	Mar. 11 to Apr. 14	34
Mar. 11 to Apr. 4	24	Mar. 21 to Apr. 24	34
Mar. 14 to Apr. 6	23	Mar. 10 to Apr. 14	35
Mar. 14 to Apr. 10	27	Mar. 17 to Apr. 22	36
Mar. 14 to Apr. 11	28	Mar. 10 to Apr. 14	35
Mar. 23 to Apr. 25	23	Mar. 10 to Apr. 14	35
Mar. 18 to Apr. 19	32	Mar. 10 to Apr. 22	43
Mar. 11 to Apr. 1	21	Mar. 14 to Apr. 13	30
Mar. 11 to Apr. 4	24	Mar. 16 to Apr. 13	28
Mar. 11 to Apr. 4	24	Mar. 18 to Apr. 18	31
Mar. 16 to Apr. 13	28	Mar. 18 to Apr. 19	32
Mar. 14 to Apr. 4	21	Mar. 12 to Apr. 21	40
Mar. 17 to Apr. 15	29	Mar. 11 to Apr. 6	26
Mar. 13 to Apr. 10	28	Mar. 14 to Apr. 11	28
Mar. 18 to Apr. 14	27	Mar. 14 to Apr. 15	32
Mar. 11 to Apr. 2	22	Mar. 14 to Apr. 11	28
Mar. 11 to Apr. 6	26	Mar. 13 to Apr. 15	33
Mar. 11 to Apr. 2	22	Mar. 11 to Apr. 6	26
Average	28.3	Average	34.5

HIBERNATION.

B. funebris hibernates in the larval stage within the infested seed, and the first larvæ enter hibernation as early as August. In fact, many larvæ, after spending a part of the summer in aestivating, continue into hibernation without resuming apparent activity. On the other hand, large numbers of larvæ of this species can be found active in the seeds throughout September and October, and a few of them have been found feeding in the green alfalfa seeds throughout the month of December and even until they were killed by heavy frosts in early January. Early spring rains, together with warm days, mark the end of hibernation for a large percentage of the larvæ.

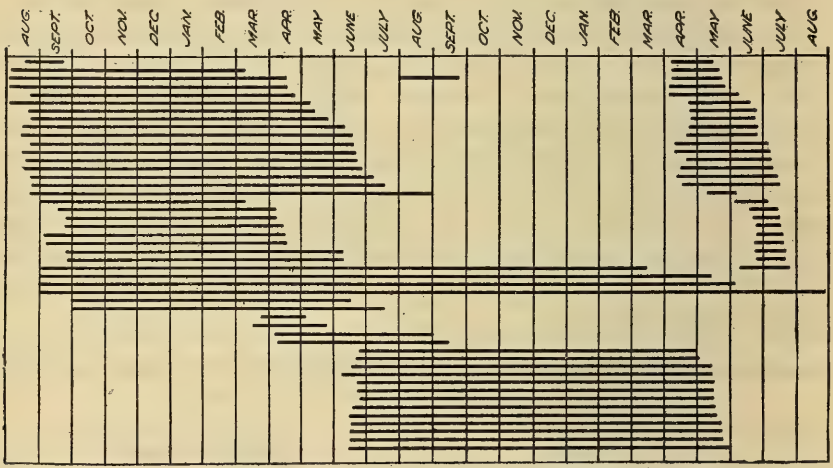


FIG. 1.—Diagram showing development of *Bruchophagus funebris.* Each heavy line shows the time required for one individual from the egg to the adult stage.

In southern California the first pupæ may be found in the latter part of February, and these increase in great numbers throughout the month of March. H. T. Osborn, formerly of the Bureau of Entomology, reported *B. funebris* entering the pupal stage at Wellington, Kans., during the month of March under conditions slightly unfavorable to pupation. Some of the individuals continue to rest in the larval stage until late in the spring, and frequently until midsummer. The greatest number of hibernating larvæ are found along the edges of the field, along fence lines, and in neglected seed fields. In fact, they may be found wherever large numbers of infested seeds have been allowed to remain on the fields unharvested.

In figure 1 each heavy line shows the time required for the development of a single individual of *B. funebris.* The different lengths of these lines show the period of development from the egg to the adult stage to be from 26 days to 24 months, and, in a few cases, to carry the individuals through two winters before the adult stage is reached.

RELATIVE INFESTATION THROUGHOUT THE SEASON.

During the season of 1915 newly formed alfalfa seed pods were taken at Bard, Calif., at intervals of about one week, and examined for infestation by the seed chalcis-fly. It was found that the seed pods taken as early as April 24 showed 39 per cent of the seeds to be infested. On May 8, as many as 52 per cent showed infestation by the chalcis-fly. This was undoubtedly due to the increased emergence of the chalcis-fly. The period from the middle of May to the middle of July, at which time the pods were forming in great abundance, showed the infestation dropping to an average of 28 per cent.

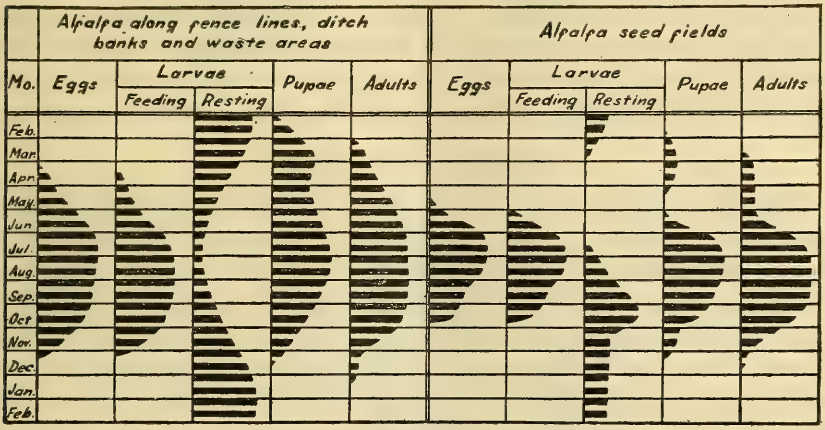


Fig. 2.—Diagram showing comparative abundance of the stages of *Bruchophagus funebris* during the different months of the year.

The average infestation for the period from the middle of July to the end of September increased to 49.5 per cent. This was undoubtedly due to the increased number of the chalcis-flies and to the rapid decrease in the seed pods caused by the cutting of alfalfa on many of the seed fields.

By October all the seed fields had been harvested, and the chalcis-flies were forced to breed in the green pods still forming along the edges of the fields. Seed pods collected on October 12 showed 85 per cent of the seeds to be infested.

Figure 2 shows the comparative abundance of the stages of *B. funebris* during the different months of the year.

It will be noted by the chart that eggs of *B. funebris* are found earlier along fence lines than in the seed field. This is due to the fact that isolated plants on waste areas form the earliest pods, and the seed fields are cut for hay before the seed crop is grown. A sudden scarcity of eggs, feeding larvæ, and pupæ is seen in the field in October, which is due to the harvesting of the latest seed crops. Resting larvæ continue to remain on the field throughout the winter in remaining seed pods, but are much more abundant along fence lines. Spring irrigation of seed fields hastens emergence of adults, and this results in the absence of resting larvæ and pupæ on most fields during the month of May.

PARTHENOGENESIS.

The parthenogenetic habit is well established in the females of this species. Female adults, reared from pupæ which were completely isolated, were placed in cages for oviposition into green alfalfa seed pods. All precautions were taken against earlier infestation of the green seeds. These virgin females oviposited freely, and their progeny was reared in breeding cages. The largest number of offspring from a single female observed by the writer was 20, and all of the progeny of these virgin females proved to be males.

CONTROL METHODS.

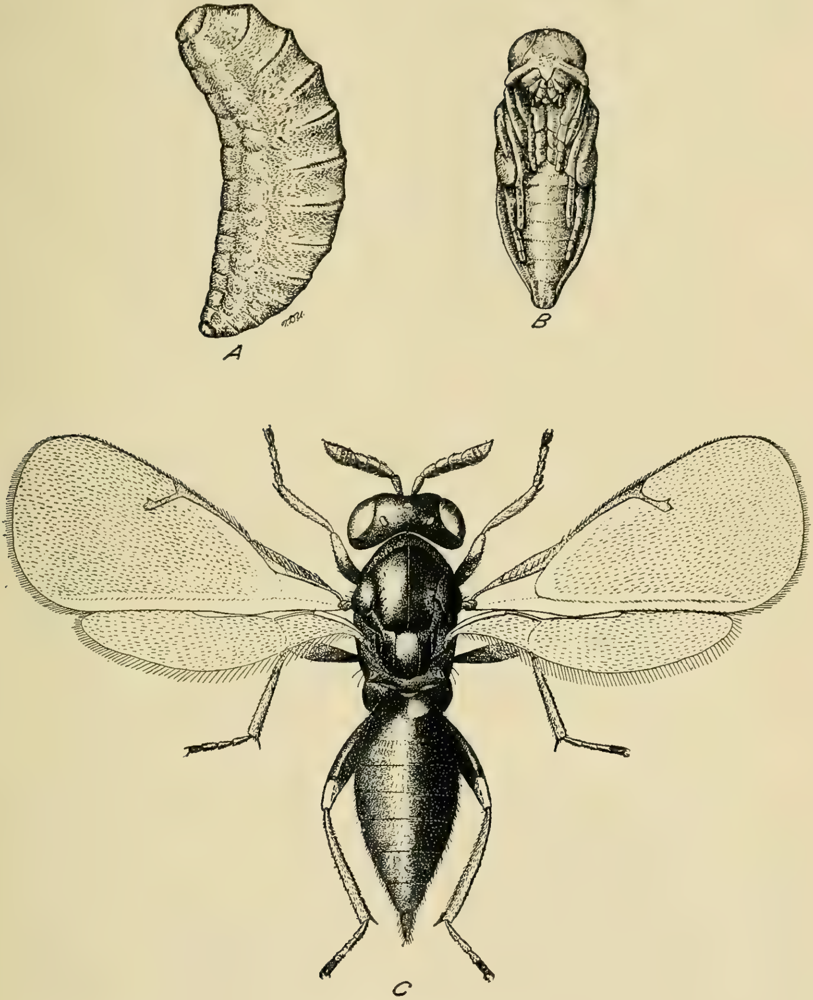
The practical methods of controlling the chalcis-fly in the alfalfa and clover seed fields are mostly cultural methods. It can not be hoped to eradicate this pest from any seed-producing locality; but with the proper methods effectively applied thousands of dollars can be saved annually to the different seed-growing districts. Because of the rapid dispersion of the adults of this species it is of vital importance that control methods should be taken up by community action rather than by the individual.

BURNING OVER OF FENCE LINES.

Everywhere in the alfalfa and red clover seed-growing districts one will find large quantities of standing plants along the fence lines and waste areas bearing the seeds infested by hibernating larvæ. Many hibernating larvæ of the chalcis-fly can be destroyed in the fall of the year by burning over such areas, thereby greatly lessening the abundant emergence of adults in early spring. It has been found that live stock can not be depended upon to rid the fence lines of standing alfalfa in the winter unless there is a great shortage of forage.

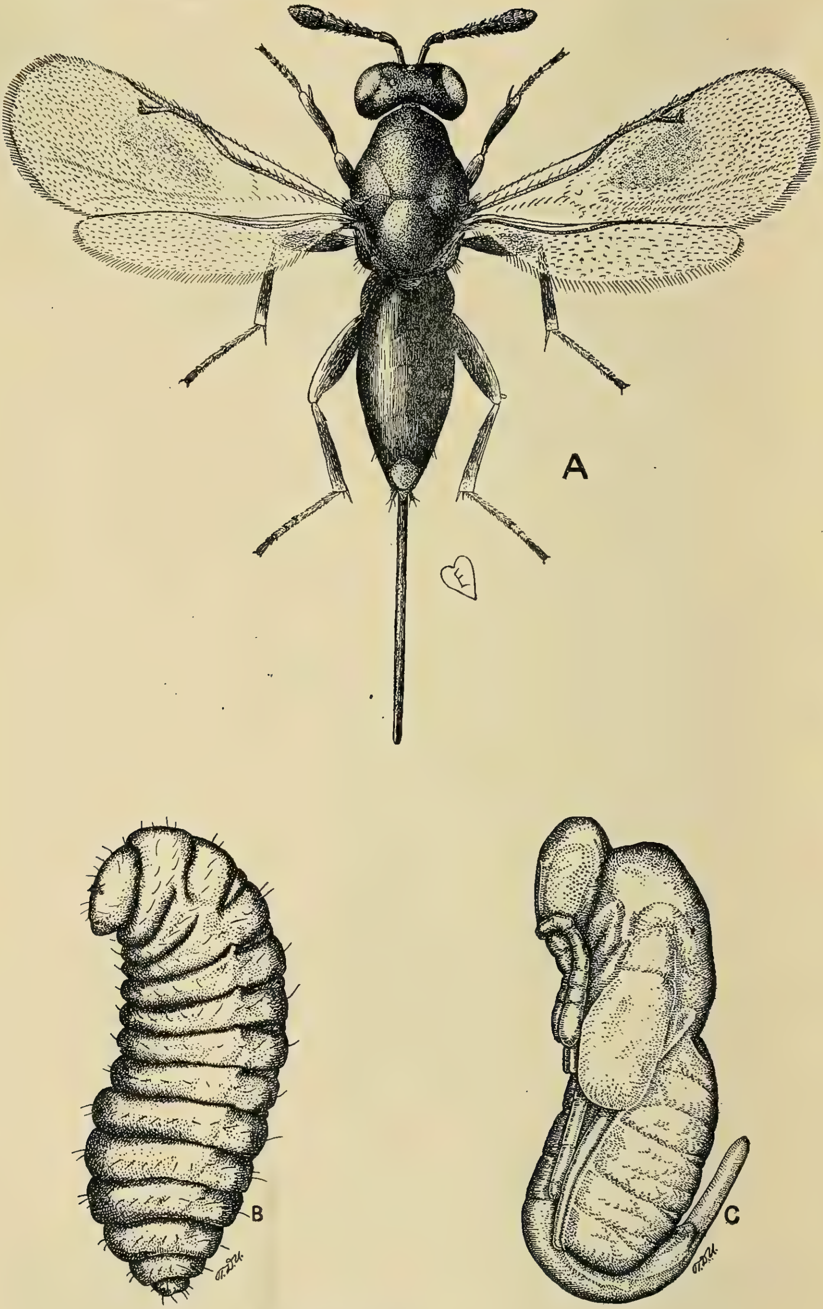
WINTER CULTIVATION.

The cultivation of alfalfa seed fields during the winter is of much value in covering the infested alfalfa seeds containing hibernating larvæ. It is not necessary that infested seeds should be covered to



TETRASTICHUS BRUCHOPHAGI.

A, Larva; B, pupa; C, adult.



LIODONTOMERUS SECUNDUS.

A, Adult female; B, larva; C, pupa.

such a depth that the emerging adults are unable to reach the surface, because the slightest covering of moist soil will cause many of the infested seeds to mold, and prevent development of the pupal or adult stages.

The necessary cultivation can be accomplished by the use of an alfalfa cultivator, spring-tooth harrow, or a disk. Care should be taken that the surface of the field is left smooth, to facilitate close cutting, as well as to prevent clods and gravel from being taken up with the seed when the seed crop is harvested.

IRRIGATION OF ALFALFA SEED FIELDS.

Whenever possible, the alfalfa seed grower should do most of his irrigating in early spring, or before the seed crop is grown. Where this can be practiced, two important points may be gained. First, the tender, rank growth of alfalfa usually following irrigation will be removed as an early fodder crop, and a steady growth of more substantial stems will take its place to produce the seed crop. Second, irrigation of a seed field stimulates the emergence of the chalcis-flies which remain within the infested seeds upon the ground. The humidity of the atmosphere over an irrigated field accelerates the emergence of this pest from seeds of the newly forming crop, which would otherwise become sufficiently dry to force many of the larvæ into a resting period.

It has been supposed by farmers that flooding the seed fields after the first crop of alfalfa has been removed would destroy the larvæ of the chalcis-fly present in alfalfa seeds upon the ground. The writer has found that soaking infested seed in water for four or five days is not sufficient to kill the larvæ resting within the seeds. This would render any attempt at their destruction by irrigation impractical.

CUTTING EARLY PLANTS ON WASTE AREAS.

The fence lines, ditch banks, and other waste areas where volunteer alfalfa can be found, are among the great sources of infestation. It has been found that the chalcis-fly frequently passes through one or two generations on this volunteer alfalfa before the seed fields are advanced to the point where infestation takes place. Every farmer, therefore, in an alfalfa seed-growing district should cut all of the standing alfalfa along the fences and waste areas at the time a hay crop is cut before he grows a seed crop. Alfalfa seed pods should not be allowed to develop anywhere around the field until the plants of the regular seed crop have begun to form pods.

CAREFUL CUTTING OF HAY CROPS.

It is of the greatest importance that special care should be exercised in cutting alfalfa or red clover before the seed crop is grown.

Any plants carelessly cut, so that some stems remain standing, and allowed to develop seed in advance of the regular seed crop, offer favorable conditions for the multiplication of the chalcis-flies. All pocket gophers should be poisoned or trapped and their mounds, as well as other irregularities in the surface of the field, should be leveled so as to make clean cutting possible.

PASTURING BEFORE GROWING SEED.

After removing the first crop of alfalfa for hay, and preparing to grow a seed crop, it is frequently possible to secure a herd of live stock, which may be turned into the field for two or three days. If a sufficient number of horses, cattle, or sheep can be secured they will render a valuable service by destroying the clusters of plants which frequently escape the mower, develop early seed pods, and form favorable breeding places for the development of the chalcis-fly before the regular seed crop has become sufficiently advanced.

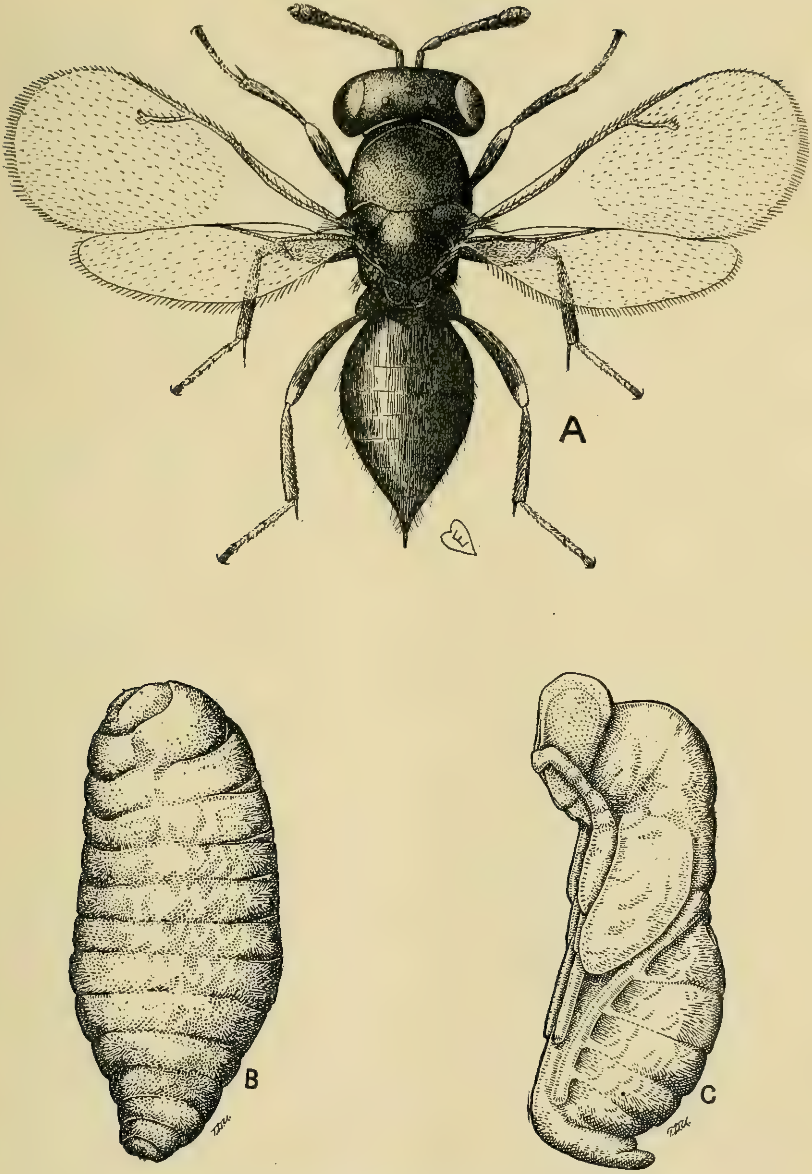
ALLOWING THE SEED CROP TO STAND TOO LONG.

The development of seed pods in the alfalfa seed fields is to a great extent periodical. That is to say, the first set of pods will have been formed when a new set of blossoms appears, or the first set of pods will be reaching maturity when the second set of pods is soft and green. This condition is most noticeable in fields receiving frequent irrigation. The tendency on the part of the farmer is to allow the seed crop to remain on the field too long, while waiting for a third or even a fourth set of pods to develop. It has frequently been observed that the chalcis-fly passes a complete generation in the earlier pods, and, in much greater numbers, infests the later pods forming on the same plants. Consequently, all seed fields should be handled, as much as possible, so that a heavy setting of pods will be secured with the first bloom and the crop removed from the field as early as possible. This will avoid a greater percentage of infested seeds as well as loss of time and will make room for the growing of subsequent crops for hay.

SECOND CROP OF SEED.

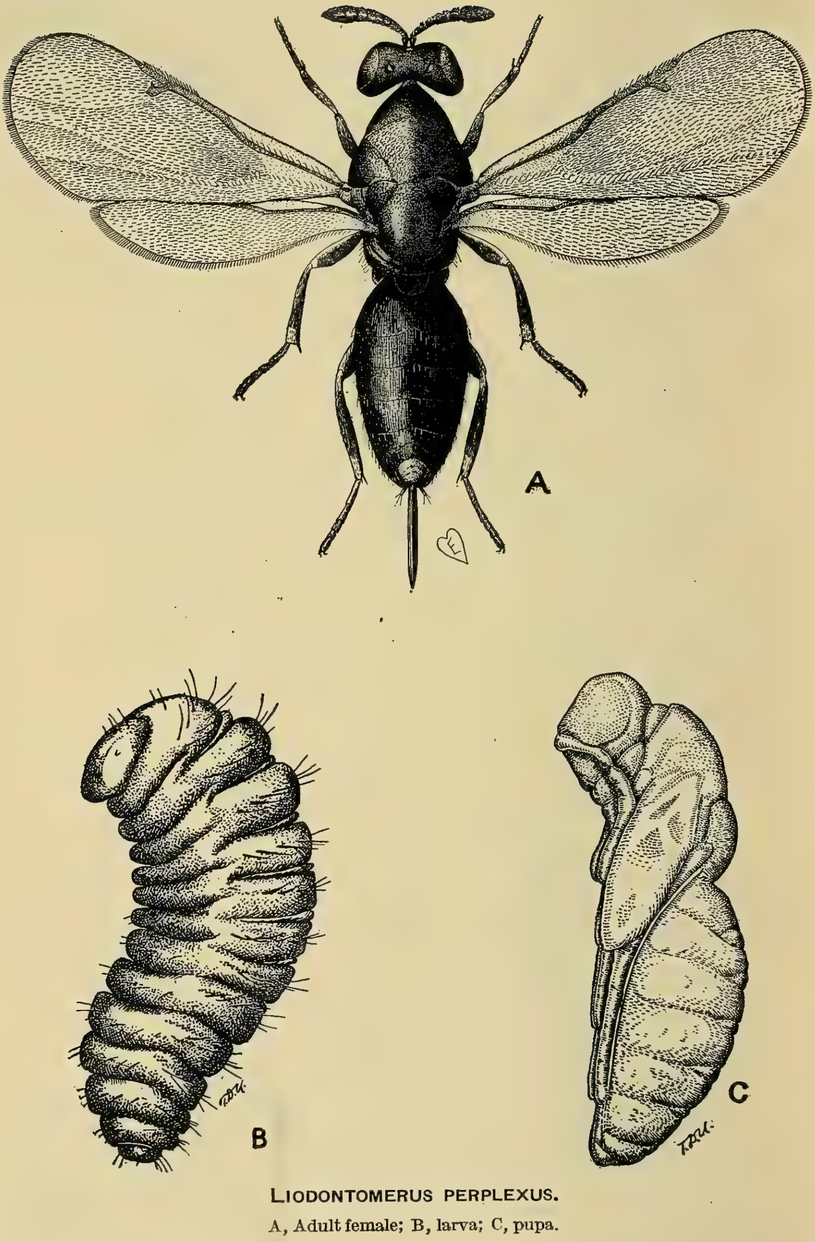
In the Southwest, where there is little danger of early frost, seed growers occasionally attempt to grow two crops of alfalfa seed in a single season. The results of such instances are usually very disappointing, on account of the usual severe infestation common to the second crop. This is frequently so great that the crop does not pay the harvesting expenses.

An attempt to grow a second crop of alfalfa seed in a single season will meet with almost certain failure as a result of the increased abundance of the chalcis-flies late in the summer.



EUTELUS BRUCHOPHAGI.

A ,Adult female; B ,larva; C, pupa.



LIODONTOMERUS PERPLEXUS.

A, Adult female; B, larva; C, pupa.

PASTURING INFESTED FIELDS.

The great mistake of pasturing alfalfa seed fields which have become too severely infested to yield a crop worth harvesting is too frequently made. Live stock walking through the ripe alfalfa cause the seeds to be shelled out and those infested with hibernating larvæ of the chalcis-fly fall on the ground, where they become the source of infestation for the following year.

HYMENOPTEROUS PARASITES.

TETRASTICHUS BRUCHOPHAGI Gahan (6).

Tetrastichus bruchophagi[1] (Pl. III) is generally distributed over most of the northern half of the United States. In the central California alfalfa seed-growing sections it is the most active of the present known parasites of *Bruchophagus funebris*. While it can not be depended upon to control the alfalfa-seed chalcis-fly, it has been observed to destroy about 50 per cent of the larvæ of the chalcis-fly normally in the fields. This species develops within the seed and feeds upon the larval stage of its host.

LIODONTOMERUS SECUNDUS Gahan (8).

Liodontomerus secundus[2] (Pl. IV) has been found by the writer to be an active parasite upon the chalcis-fly when the latter infests the seeds of red clover. It does not seem to attack the chalcis-fly larvæ infesting alfalfa seeds. This species is apparently most active in the red-clover seed-growing sections of Oregon and Idaho. It is active in the fields throughout the summer and hibernates in the larval stage within the infested seeds left on the field.

EUTELUS BRUCHOPHAGI Gahan (8).

Eutelus bruchophagi[2] (Pl. V) is of economic importance as a parasite of the chalcis-fly in the mountain valleys of southern Idaho and central Utah. It has also been found by the writer east of the Sierra Nevada Mountains in northern California. It does not appear to be present in the southwestern alfalfa seed-growing districts.

LIODONTOMERUS PERPLEXUS Gahan (8).

Liodontomerus perplexus[2] (Pl. VI) is a parasite of considerable importance in checking the abundance of the chalcis-fly breeding in alfalfa seeds throughout western Arizona. It was reared as far north as South Dakota by C. N. Ainslie. This parasite attacks the larvæ of its host, and develops within the infested seeds. It has not been observed attacking the chalcis-fly when the latter infested seeds of red clover. This species is most active during midsummer. It appears slower in resuming activity in spring than the other species studied.

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[1] For a more complete account of the species, see Urbahns (10).

[2] For a more complete account of this species, see Urbahns (11).

HABROCYTUS MEDICAGINIS Gahan (7).

Habrocytus medicaginis[1] (Pl. VII) is present throughout California, Idaho, Utah, and parts of Arizona. It has also been reported from South Dakota, Kansas, New Mexico, Nevada, and Oregon. While this parasite can not be depended upon at the present time to control the chalcis-fly in any locality where it has been observed, it is of value in checking the abundant development of its host. This species is parasitic externally upon the larvæ of its host, and completes its development within the infested seed.

From all observations, *Habrocytus medicaginis* attacks the chalcis-fly only when the latter infests the seeds of alfalfa. This parasite has never been found upon the same host within red clover seeds.

TETRASTICHUS VENUSTUS Gahan (7).

Tetrastichus venustus does not occur in sufficient numbers to be considered of economic importance as a parasite of the chalcis-fly in alfalfa seeds. While this species has been reared in small numbers from alfalfa seeds infested with the seed chalcis-fly, and is without doubt a parasite of the latter, the larval stage has not been recognized. Specimens were reared by the writer from Corcoran, Red Bluff, and Tulare, Calif., and from Yuma, Ariz.

TRIMEROMICRUS MACULATUS Gahan (6).[2]

Trimeromicrus maculatus (Pl. VIII) is of economic value as a parasite of the alfalfa-seed chalcis-fly throughout Arizona and California. It has been found especially active in the Buckeye and Yuma Valley seed districts of Arizona, and in the Honey Lake and Imperial Valleys of California.

LIODONTOMERUS INSUETUS Gahan (8).

Notes on file in the Bureau of Entomology, made by H. T. Osborn, under date of September 19, 1910, show the larvæ of this species to be parasitic upon larvæ of *Bruchophagus funebris*. Specimens in the National Museum were reared by C. N. Ainslie, Mesilla

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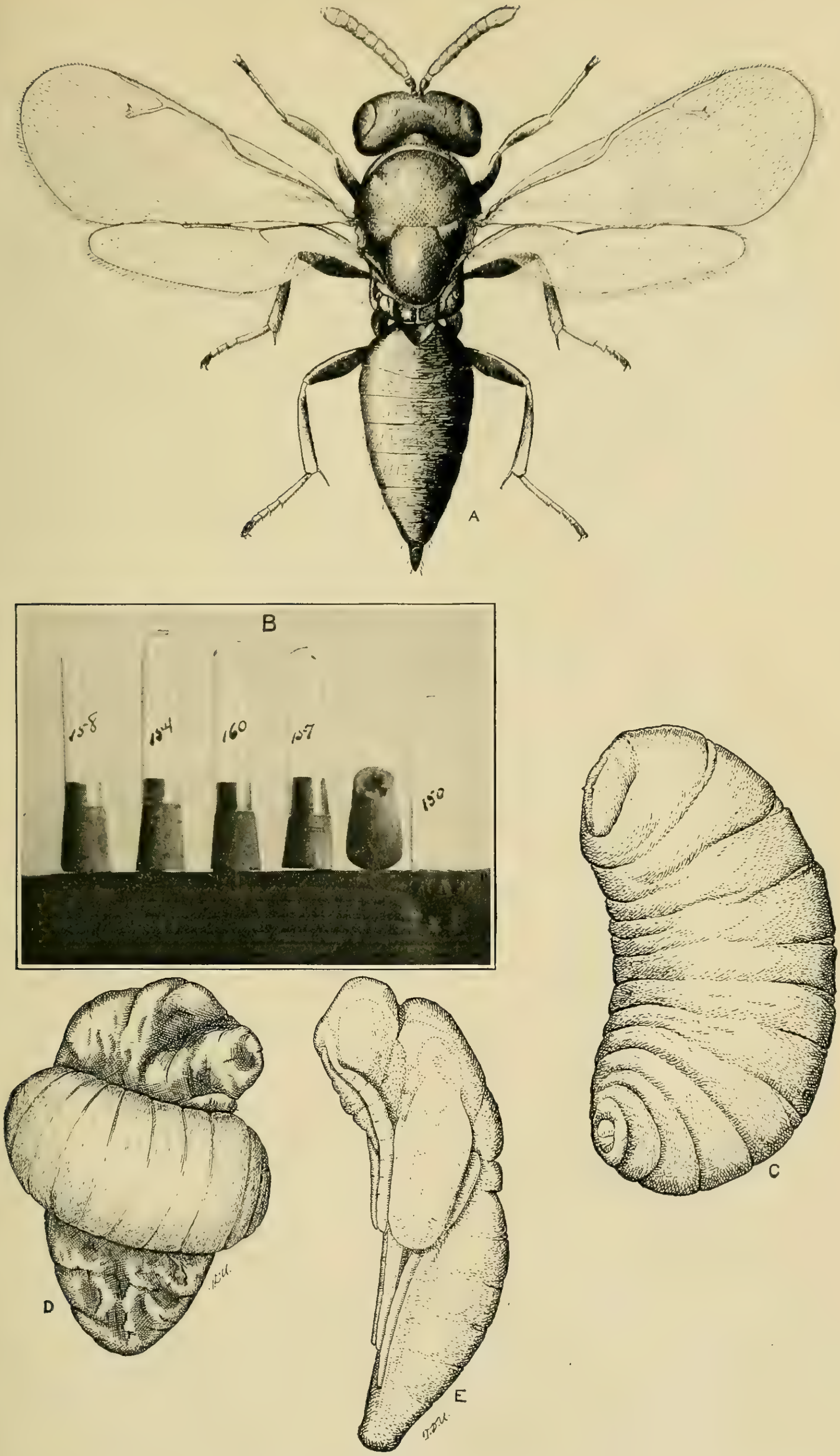
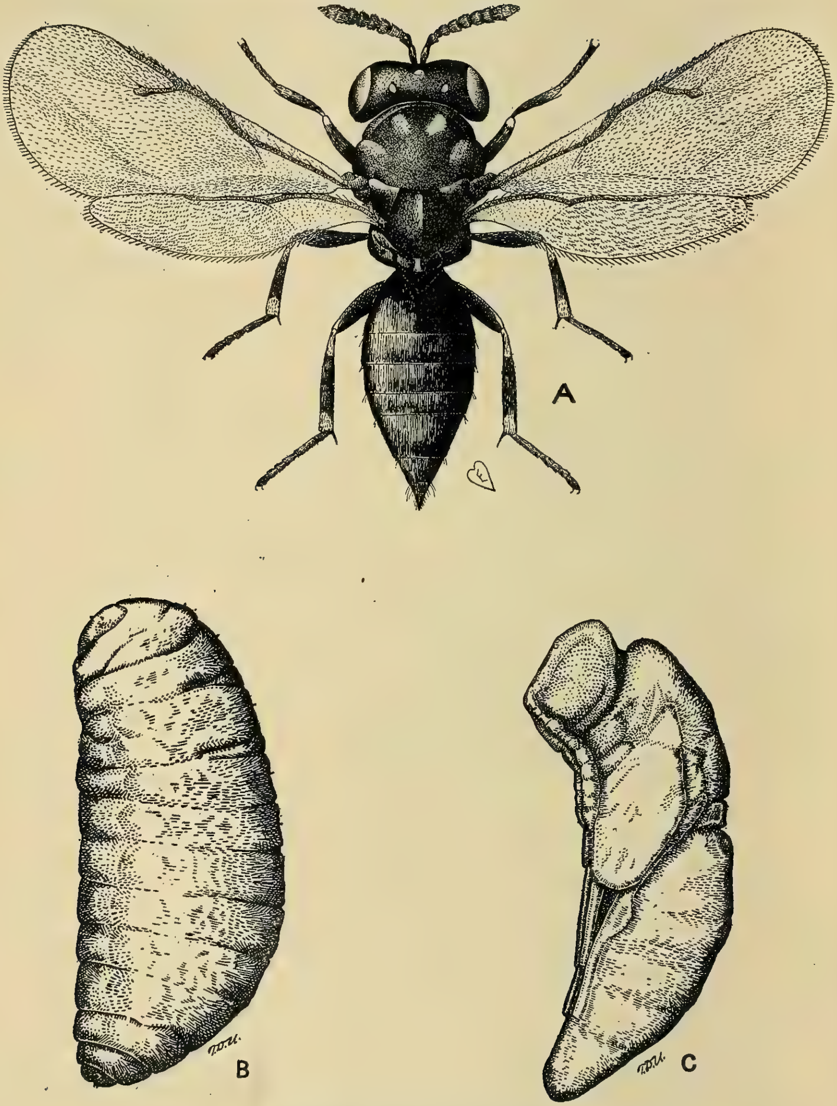
[1] For a more complete account of this species, see Urbahns (9).

[2] For a fuller description, see Urbahns (11).



HABROCYTUS MEDICAGINIS.

A, Adult; B, cages for rearing parasite larvae; C, larva; D, larva destroying its host larva; E, pupa.



TRIMEROMICRUS MACULATUS.

A, Adult female; B, larva; C, pupa.

Park, N. Mex.; H. T. Osborn and E. G. Kelly (1910), Wellington, Kans.; E. G. Smyth and R. N. Wilson, Tempe, Ariz.; and by E. G. Kelly, Sedgwick, Kans. (1914).

The economic importance of this species as a parasite of the chalcis-fly is not known at the present time.

EUPELMUS sp.

A single larva of this species was dissected from an alfalfa seed by M. Marshall, and was found to be parasitic upon the larva of *B. funebris* infesting the seed. The specimen was taken at Pasadena, Calif.

The larva of this species measured about 1.6 mm. in length, and was almost white in color. The head was small and the chitinous mandibles distinctly visible. The body segments were conspicuous and covered with fine pubescence. The larva was rather active.

The pupa, at first white, turned to a smoky-white color, and almost black before the emergence of the adult.

PREDACIOUS MIDGE.

LESTODIPLOSIS sp. Felt.

Larvæ of a midge, described as *Lestodiplosis* sp. by Dr. E. P. Felt, were found in infested alfalfa seeds, where they had apparently destroyed the larva of *B. funebris.* It is quite probable that larvæ of this midge confine themselves to cracked or broken seeds, and where the larva of the chalcis-fly is exposed. The specimens under observation were taken in San Diego County, Calif.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 813
Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER June 25, 1920

CITRUS-FRUIT IMPROVEMENT: A STUDY OF BUD VARIATION IN THE EUREKA LEMON.[1]

By A. D. Shamel, *Physiologist*, L. B. Scott, *Pomologist*, C. S. Pomeroy, *Assistant Pomologist*, and C. L. Dyer, *Scientific Assistant, Fruit-Improvement Investigations, Office of Horticultural and Pomological Investigations.*

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IMPORTANCE OF THE LEMON INDUSTRY.

The lemon (*Citrus limonia* Osbeck), as grown in the United States, is largely a California product. According to the Thirteenth Census of the United States there were 957,000 lemon trees of bearing age in the United States in 1910 and 396,000 under bearing age, of which 941,293 and 379,676, respectively, were in California. The total production of all States in 1909 was reported as amounting to 2,770,313 boxes, of which California produced 2,756,221 boxes.

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[1] This is the fourth in a series of bulletins summarizing the citrus fruit-improvement investigations of the Department of Agriculture. The three former reports, U. S. Dept. Agr. Buls. 623, 624, and 697, presented the results of studies with the Washington Navel orange, the Valencia orange, and the Marsh grapefruit, respectively. A report on bud variations in the Lisbon lemon will be found in U. S. Department of Agriculture Bulletin 815, entitled "Citrus-Fruit Improvement: A Study of Bud Variation in the Lisbon Lemon."

The commercial development of the lemon industry in the United States is of comparatively recent date. The total production in 1899 was 877,000 boxes as compared with 2,770,000 boxes in 1909, an increase of 215.9 per cent. The rapidity of the development of lemon production in California is shown in Table I.

TABLE I.—*Shipment of lemons from California,*[a] *for the 32-year period from 1887 to 1918, inclusive.*

Year ending. Oct. 31.	Carloads.[b]	Year ending Oct. 31.	Carloads.[b]	Year ending Oct. 31.	Carloads.[b]	Year ending Oct. 31.	Carloads.[b]
1887	12	1895	335	1903	2,649	1911	6,891
1888	20	1896	565	1904	2,782	1912	6,133
1889	26	1897	1,378	1905	4,274	1913	[c] 2,304
1890	34	1898	1,166	1906	3,789	1914	[c] 3,032
1891	40	1899	903	1907	3,507	1915	7,068
1892	52	1900	1,447	1908	4,959	1916	7,186
1893	65	1901	2,924	1909	6,196	1917	7,915
1894	145	1902	2,816	1910	4,891	1918	[d] 6,337

[a] Wallschlaeger, F. O. The world's production and commerce in citrus fruits and their by-products. Citrus Prot. League, Cal., Bul. 11, p. 69. 1914. Data from 1914 to 1918 furnished by the California Fruit Growers' Exchange.

[b] The average number of boxes per car for lemons has varied from 310 to 390.

[c] Crops of 1913 and 1914 reduced by frosts.

[d] Crop of 1918 reduced by extreme heat in 1917.

The lemon acreage in the counties of California where this industry is most important and the production in the leading counties in 1917 are shown in Table II, which also shows the location of the principal lemon districts in the State.

TABLE II.—*Acreage and fruit production of lemon trees in the principal lemon-producing counties of California, in 1917.*[a]

Counties.	Acreage, 1917		Production, 1917.	Counties.	Acreage, 1917.		Production. 1917.
	Bearing.	Non-bearing.			Bearing.	Non-bearing.	
			Pounds.				*Pounds.*
Los Angeles	3,801	1,270	85,520,000	Tulare	1,132	1,534	4,160,000
Orange	4,000	2,300	23,400,000	Ventura	2,327	3,980	32,768,000
Riverside	3,137	2,395	27,448,000	All others	364	1,300	132,000
San Bernardino	3,549	2,850	31,954,000				
San Diego	3,126	2,071	17,584,000	Total	22,451	17,940	236,966,000
Santa Barbara	1,015	240	14,000,000				

[a] Compiled from the reports of the County Horticultural Commissioners by Geo. P. Weldon, Chief Deputy and O. W. Newman, Assistant Secretary, State Commission of Horticulture.

Some idea of the extent to which California is supplying the market requirements for lemons in the United States may be gained by referring to Table III, which presents a comparison of all the imports of lemons into the United States, except from Cuba, and the shipment of California lemons.

The Eureka, Lisbon, and Villa Franca are the important varieties of lemons grown in California. The Eureka variety is the most widely grown. The Lisbon variety is extensively grown in certain districts, particularly those near the coast, and its trees are being planted in increasing numbers. The Villa Franca variety was used extensively during the early period of commercial lemon planting, but at the present time its propagation has been almost abandoned.

Table III.—*Imports of lemons into the United States compared with lemon shipments from California, for the 19-year period from 1900 to 1918, inclusive.*

Year.	Imports.[a]	Shipments from California.[b]	Year.	Imports.[a]	Shipments from California.[b]	Year.	Imports.[a]	Shipments from California.[b]
	Pounds.	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
1900...	160,198,056	43,410,000	1907...	157,859,906	105,210,000	1913...	151,416,412	[c] 69,120,000
1901...	148,514,614	87,720,000	1908...	178,490,003	148,770,000	1914...	58,019,405	[c] 90,960,000
1902...	164,075,309	84,480,000	1909...	135,183,550	185,880,000	1915...	(d)	212,040,000
1903...	152,004,213	79,470,000	1910...	160,214,785	146,730,000	1916...		215,580,000
1904...	171,923,221	83,460,000	1911...	134,968,924	206,730,000	1917...		237,450,000
1905...	139,084,321	128,220,000	1912...	145,639,396	183,990,000	1918...		[e] 190,110,000
1906...	138,717,252	113,670,000						

[a] Years ending June 30. Figures from the Bureau of Foreign and Domestic Commerce, U. S. Department of Commerce.

[b] Years ending October 31. Figures from the California Fruit Growers' Exchange.

[c] Crops of 1913 and 1914 reduced by frosts.

[d] Imports from 1915 to 1918 are expressed in values rather than pounds and for this reason are not here presented.

[e] Crop of 1918 reduced by extreme heat in 1917.

HISTORY OF THE EUREKA VARIETY.

The Eureka variety originated in Los Angeles, Calif. In 1858 Dr. Halsey, a physician of that city, received from New York City a box of Sicilian lemons. From seeds of these fruits he grew a number of trees in a small nursery which he owned on Alameda Street, Los Angeles, near the present site of the Southern Pacific Railroad depot. In 1860 Mr. Andrew Boyle purchased from Dr. Halsey several hundred of these seedling trees. They bore very lightly until 1870 and 1871, at which time three or four of them were found to produce smooth, thin-skinned fruits very different from the thick-skinned and coarse-textured fruits produced by the other trees. In 1877 Mr. W. H. Workman, son-in-law of Mr. Boyle, gave to Mr. Thomas A. Garey, a prominent horticulturist of Los Angeles, buds taken from one of the seedling trees which was bearing smooth, thin-skinned lemons.[1] Mr. Garey propagated these buds, and the trees grown from them were found to bear lemons of superior quality. A large stock of the trees of this variety was then grown and distributed under the name of Garey's Eureka.[2] Later, by common consent, the name of the variety was shortened to Eureka, under which name it is now generally propagated and grown.

VARIABILITY WITHIN THE VARIETY.

The systematic studies of the variations of the California citrus varieties were begun with the Washington Navel orange in 1909. While carrying on studies of the variations of the Marsh grapefruit, the striking variability of Eureka lemon trees in a neighboring orchard was discovered. This orchard consisted of about 16,000 trees which were six years old at that time. The buds from which the trees had been propagated were obtained from a well-known productive Eureka orchard in the same locality. The buds were procured in the customary way, two men having been sent to cut them with no thought of selection from superior individual trees.

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[1] Personal statement of Mr. W. H. Workman, 310 Washington Building, Los Angeles, Calif., March 21, 1917.

[2] Letter from Mr. A. T. Garey, son of Mr. Thomas A. Garey, 200 West 47th Street, Los Angeles, Calif., March 19, 1917.

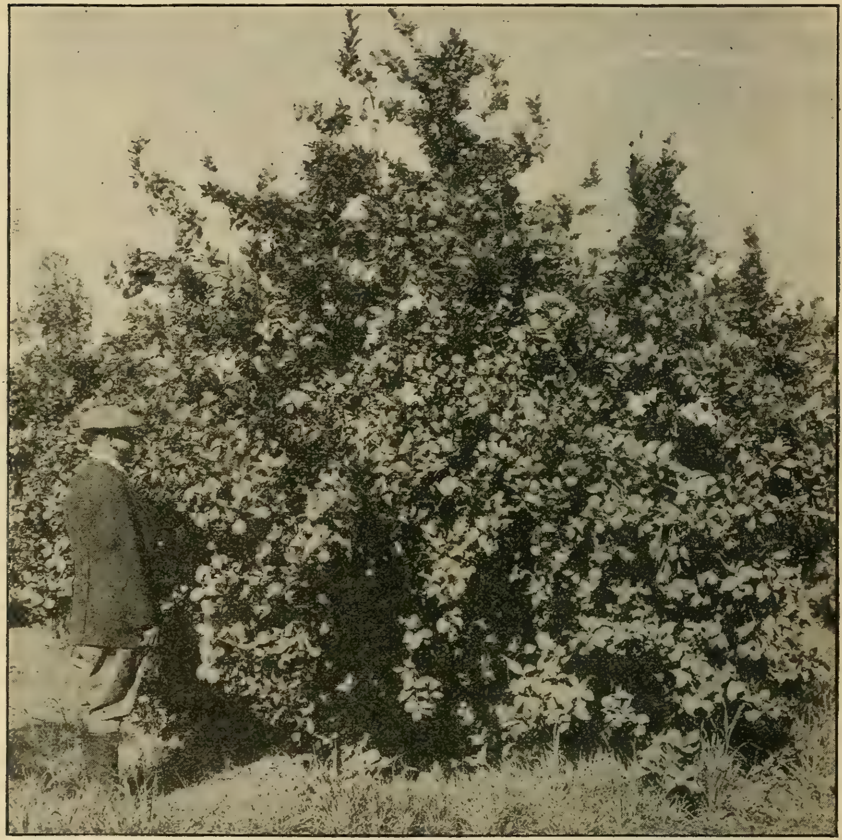

FIG. 1.—A typical lemon tree of the Eureka strain, 10 years planted. All of its branches are bearing flowers or fruits in various stages of development.

The usual habit of growth of the productive Eureka trees under observation was open and somewhat drooping (fig. 1), and the trees had medium-sized leaves which were oval and rounded in shape. The fruitful trees were bearing heavy crops of fruit during June, 1911, and every branch was apparently carrying blossoms and lemons in varying stages of development.

However, here and there trees were observed having a very different habit of growth and condition of fruitfulness. These trees had a spreading habit of growth with large and sharply pointed leaves and few blossoms or fruits. The fruits were usually ridged, rough in texture, with very thick peel and very little juice (Pl. II), in striking contrast with the smooth, very juicy, and thin-skinned (Pl. I) lemons borne by most of the trees. The unproductive trees were usually much larger than the productive ones, and the foliage was characteristically more dense and abundant. For these reasons they were commonly called shade trees.

The differences in tree and fruit characteristics of the two types of trees were so distinct and marked that typical trees of each strain could be determined at a glance and from a considerable distance.

A careful individual-tree census of the 16,000 lemon trees in this orchard was made during June and July, 1911. As a result, 2,200 trees, or 14 per cent, were found to have typical characteristics of the Shade-Tree strain. Furthermore, the systematic study of the trees revealed the presence of other undesirable strains not noticed at first.

In order to throw some light, if possible, upon the large proportion of unproductive trees in this orchard, an individual-tree census was made of the parent orchard from which the buds had been procured. It was found that in the parent orchard only 5 per cent of the total number of trees were of the Shade-Tree strain. The explanation of this condition was found to be that the bud cutters found it easier to secure bud wood from the vigorous vegetative shade trees than from the less vigorous growing productive trees. There were many more vegetative branches, then commonly used for propagation, in the shade trees than in the productive trees. Consequently, without careful individual-tree selection based on performance records, the bud cutters naturally secured more bud wood from the shade trees than from the productive trees.

Characteristic differences in the trees of the several strains of the Eureka lemon variety were found to exist not only as shown by the habit of growth, the amount and the commercial quality of the fruits, the density and other characteristics of the foliage, but also in the season of production of the fruits, the number and size of thorns, the number, size, and shape of the seeds contained in the fruits, the structure of the flowers, and the variability of the fruits.

Tree-census studies in many Eureka lemon orchards have revealed the fact that the variety is made up of a number of diverse strains arising from the propagation of striking bud variations. This condition of variability is important commercially, from the fact that the production of some of the strains is small and of very inferior quality, while other strains bear their crops during the late fall or very early spring when low lemon prices are the rule, making the crops of inferior value.

In these studies detailed performance records have been obtained on a total of 252 Eureka[1] lemon trees in the investigational plats. The individual trees in these plats have been picked monthly as far as possible. The frequent pickings and the resulting large amount of detailed work in assorting, classifying, counting, weighing, and recording the yields has made it necessary to limit to a comparatively small number the trees selected for individual-tree performance-record studies. The many pickings during a period of several consecutive years have resulted in the accumulation of a very large mass of data and information, from which conclusions have been drawn as to varietal, strain, and individual-tree characteristics.

In addition to these detailed studies, cooperative individual-tree performance records have been carried on in several California lemon orchards during this period with about 14,000 trees of the Eureka variety.

The variability of the Eureka lemon described in the discussion of the results of these studies, due to bud variations, must be clearly distinguished from the fluctuating variability due to climatic, soil, cultural, or other environmental influences. The variations considered in these studies are those which have been found to be inherent and transmitted by budding. The fluctuating variations, such as modifications of the size of the fruits, slight differences in the color of the leaves or fruits, and similar changes due to climatic conditions, cultural factors, or other causes, have not been taken into account except as indicating the effect of certain environmental factors in tree and fruit development. All of the variations considered in these studies have been traced to individual fruit or limb variations in trees growing under normal conditions.

OBJECTS OF THE INVESTIGATIONS.

The objects of these investigations have been to determine the frequency and importance of bud variations in lemon trees of the Eureka variety; to ascertain the relative value for commercial orcharding of the various strains originating from bud variations; to discover methods for isolating the best and eliminating the inferior strains through bud selection; to originate and introduce methods for replacing trees of inferior strains in established orchards through top-working or replanting; to introduce methods for obtaining reliable supplies of buds from superior performance-record trees for use by propagators; and to establish a system of individual-tree record keeping in commercial lemon orchards, in order to locate the desirable and undesirable trees.

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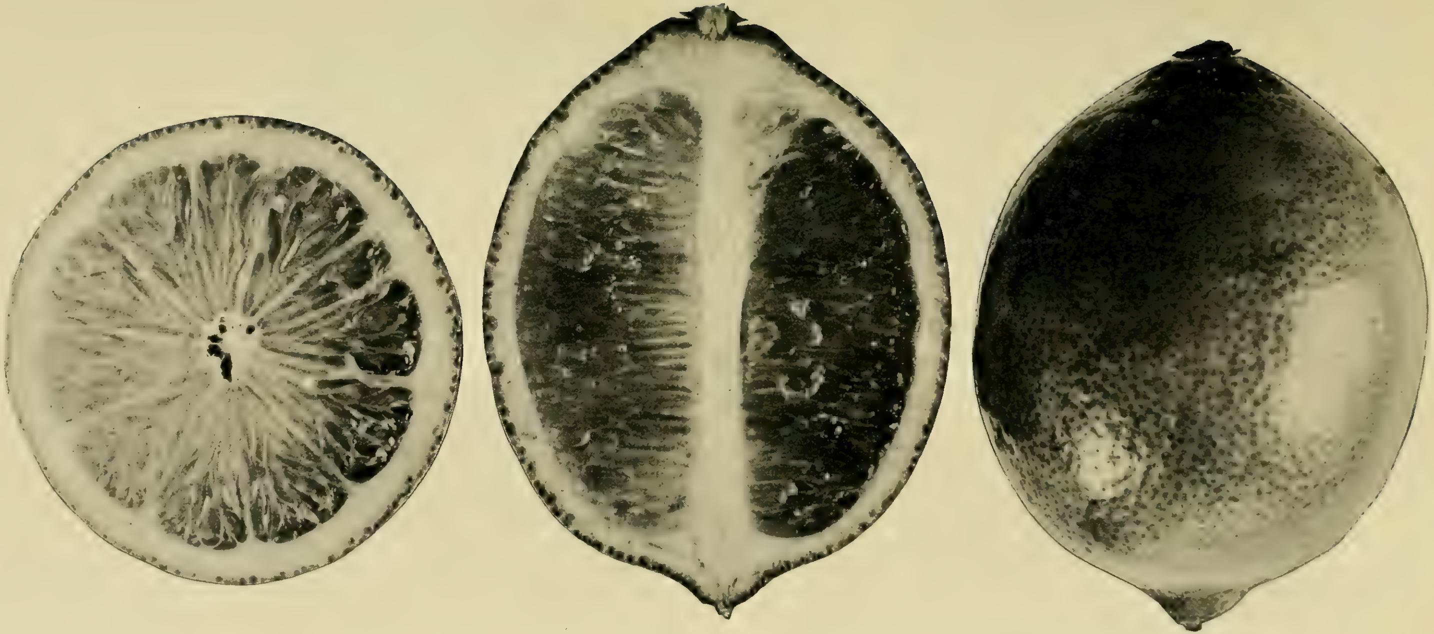
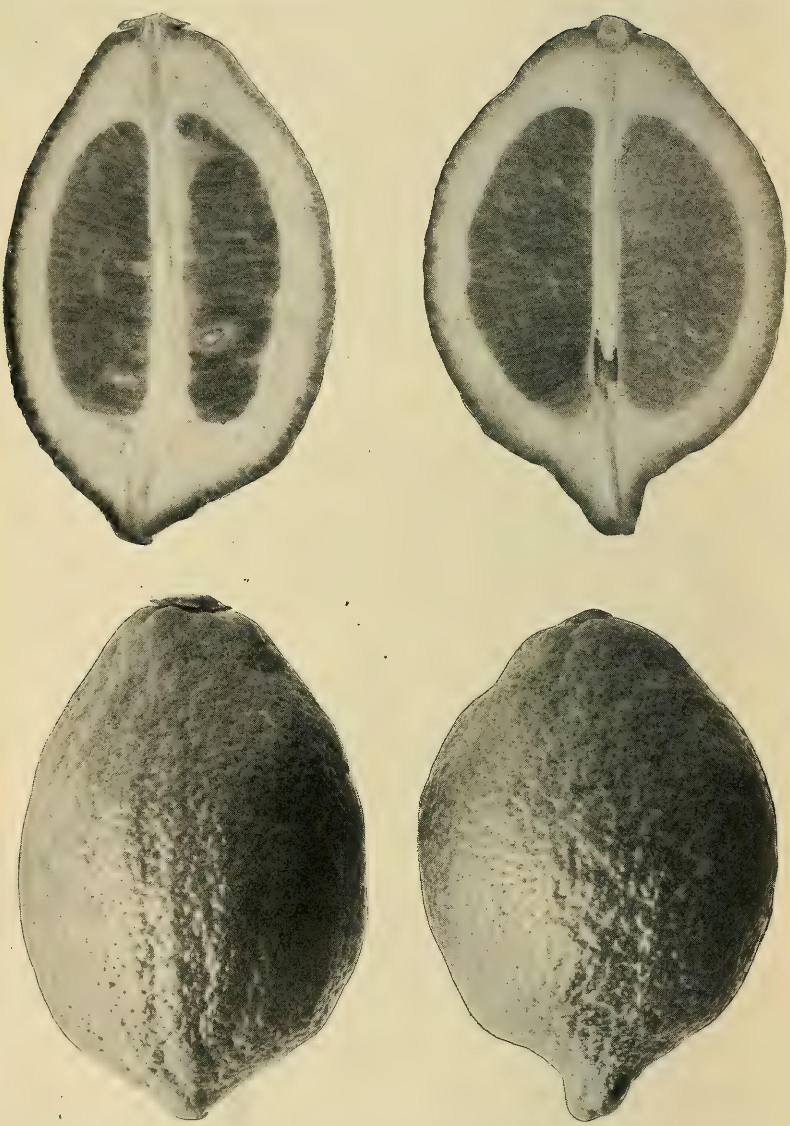
[1] A report on variations in the Lisbon variety will be found in Department of Agriculture Bulletin No. 815, entitled "Citrus-Fruit Improvement: A Study of Bud Variation in the Lisbon Lemon."



TYPICAL LEMON FRUITS OF THE EUREKA STRAIN OF THE EUREKA VARIETY.

All the specimens here illustrated, including the cross section, the axial section, and entire fruit, were fresh, uncured samples. Natural size.



TWO TYPICAL LEMON FRUITS OF THE SHADE-TREE STRAIN OF THE EUREKA VARIETY.

The long shape, coarse texture, and thick rinds of these fruits make them of inferior commercial value. About three-fourths natural size.

PLAN OF THE INVESTIGATIONS.

These investigations have been carried on by means of individual-tree performance records. The term "performance record" is here used to mean a systematic record for a period of several years of the yield and behavior of individual trees. This record includes accurate notes of the number, the commercial quality, and the variability and other characteristics of the fruits produced by the individual trees. It is usually accompanied by descriptive notes and photographs, or drawings, showing the characteristics of the habit of growth, the leaves and flowers, and the position or arrangement of the fruits on the trees. Individual-tree performance records for at least two consecutive and normal seasons on lemon trees which have reached full bearing age are considered necessary in order to determine the value of the trees for commercial fruit production. Similar records for at least four years are advisable, in order to furnish an adequate basis for the selection of superior trees as sources of bud wood for propagation.

The performance records presented in this bulletin have been made from full-bearing trees located in successful commercial orchards where the conditions have been particularly favorable for comparative individual-tree studies. It has been possible to compile these records only through the hearty cooperation of the owners of the orchards selected for study. The picking of the fruits has usually been done by members of the regular picking crew. The assorting, weighing, and counting have been done by the writers in the orchards immediately after the fruits have been picked. The crops of fruit, after the records have been finished, have been turned in with the crop from the orchard as a whole, except such specimens as have been needed for further study. Owing to the additional handling necessary for the classification of the fruits, particular care has been used in order to avoid as far as possible all mechanical injuries, which frequently lead to decay and consequent loss to the growers.

The conditions considered in the location of the individual-tree performance-record plats were as follows: (1) The production of successful and profitable crops of fruit; (2) location on virgin land, in order to avoid any influence of previous cultural treatments; (3) protection from cold, strong winds, or other climatic causes of tree and fruit injuries; (4) the absence of radical pruning, rebudding, top-working, or other similar tree treatments; (5) freedom from or the effective control of diseases and insect pests; (6) uniform irrigation and cultural practices during the entire history of the orchard; (7) reliable information concerning the history of the buds used in the propagation of the trees and the kind of stocks; (8) the prospect of settled ownership for a period of years; and (9) the absence of apparent local environmental factors influencing tree behavior, in order that the results of the individual-tree studies might be truly comparative.

As a result of experience in similar work with other varieties, the performance-record plats of Eureka lemons were located so that they included representative trees of several important strains. The records of the performance of these typical trees constitute the basis for comparing the production of the different strains and their value for commercial orcharding.

The original plat included 105 trees. Later, additional trees representing important strains were added, in order to secure as complete information as possible concerning the variability of the strains. By the selection of plats in uniform soil areas and in sections with the same altitude, like exposure, and comparative drainage conditions, it is believed that the results obtained are less affected by fluctuations due to variations in soil fertility, soil moisture, and other environmental factors than would be the case if the records of all of the trees in the orchards were used for comparison.

METHODS OF KEEPING PERFORMANCE RECORDS.

The methods of keeping the individual-tree performance records in the lemon plats were adopted as a result of the experience gained during the preceding similar study of orange and grapefruit trees.

These methods involve more detailed observations than is usually considered necessary in commercial-orchard practice. A modification of these methods, adapting them for regular lemon-tree record keeping, is described in Farmers' Bulletin 794, entitled "Citrus-Fruit Improvement: How to Secure and Use Tree-Performance Records."

TREE NUMBERS.

The individual lemon trees were given numbers so that the data obtained from the study of each tree could be kept separate during the entire period of observation. Each number consists of three parts —the number of the block in which the tree occurs, the number of the row in the block, counting from some fixed point (as, for example, the irrigation head), and the number of trees in the row. Where several different orchards are under observation, the tree number is preceded by the name of the orchard or an abbreviation indicating it.

In the case of bearing trees it is most desirable to paint the number on the tree trunk or on one of the main limbs. The figures should be large and plain, so as to be readily identified from some distance. Ordinary white-lead paint and a small brush are the materials used for tree numbering. The numbers, when properly applied, have remained in a satisfactory condition for six or seven years. Where it is desirable to number small trees, the number may be stamped on a metal tag, or painted on a wooden label, and attached to one of the branches. The numbers should always be placed in the same relative position on all of the trees, so that they can easily be found.

PICKING.

The fruits borne by the trees in the performance-record plats were picked when reaching a certain size, as determined with the aid of metal picking rings, using each month a ring of the same size as that used by the regular picking crew in the orchard. While the sizes of rings varied somewhat with different pickings, all of the fruits of each picking were measured with a ring of the same size, so that the pickings from the individual trees were comparable. Particular care was taken that no mixing or loss of fruits from the individual trees occurred. The fruits from all the trees picked during the day were studied the same day, after which they were sent to the packing house to be included with the remainder of the crop. The clippers used by the pickers, the picking sacks, and the field boxes were all regularly inspected, in order to prevent as far as possible mechanical injuries to the fruits, which frequently lead to decay. Every effort was made to arrange the picking and handling of the fruits from the performance-record trees so as to cause the least possible inconvenience and loss to the owners of the orchards.

ASSORTING.

The lemons from each of the performance-record trees at each picking were assorted into three grades, viz, Green, Tree-Ripe, and Cull. In the Green grade both the light and dark green fruits were included; the Tree-Ripe grade included the yellow ripe fruits, and the Cull grade included unmerchantable lemons. The Green grade was made up of the valuable commercial fruits. The Tree-Ripe grade was made up of mature or prematurely ripened fruits, usually of small size with thin rinds and an abundance of juice which was lacking in acidity. Fruits of the Cull grade were frequently extremely coarse, rough, or malformed, rendering them unfit for the market. Fruit which dropped to the ground between picking periods was also included in the Cull grade.

After the fruits from each tree were assorted, each lot was weighed and the number of lemons counted. These data were recorded in the field-note forms, as shown in Table IV.

The variable fruits in each picking from each tree were sorted and classified, after the other performance-record data had been recorded. Frequently, samples of fruits were saved for photographing or for special studies. In some cases photographs and notes of the trees were taken, showing their habits of growth, the characteristics of the foliage or flowers, and other phases of tree behavior.

At the time of each picking, one fruit of the Green grade, one of the Tree-Ripe grade, and one of the Cull grade were selected from the crop of each tree and examined for seeds. The fruits were cut, the seeds carefully removed, counted, dried, and reserved for further study.

In the event that any samples of fruits of any of the grades were missing, so that the seeds could not be counted, a statement of this fact was made in the note form by using the words "Not counted." Figure 2 shows the simple equipment used in making individual-tree performance records and the method of handling it.

TABLE IV.—*Forms for field use in investigational work for making individual-tree performance records, showing the data from four lemon trees of the Eureka variety on the Chase plantation for the picking in April, 1916.*

[Horticultural and Pomological Investigations, B. P. I. form 110 B. Space is provided for recording the gross, tare, and net weights, or for the data for two boxes of fruit separately for each tree. These four trees are listed in ranks 105, 35, 82, and 34, respectively, in Table VI and in figure 9. The record for tree 34-75-16 for the season of 1915-16 is shown in Table V, and its record for six seasons is tabulated in rank 35 in Table VIII.]

A.—*Front of sheet, showing the form for recording the weight and number of the fruits of the different grades and the number of seeds in three typical fruits from each tree.*

Grove, *Chase plantation*; Plat, *34*. Row, *75*. Date, *April 28, 1916*. Variety, *Eureka*.

Tree No.	Fruits.								Seeds.		
	Green grade.		Tree-Ripe grade.		Cull grade.		Total crops.		Green grade.	Tree-Ripe grade.	Cull grade.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.			
	Lbs. oz.		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*				
34–75–15	22–15										
	[a]11–15										
	11– 0	38	0–12	3	0– 4	2	12– 0	43	5	0	5
34–75–16	55– 3										
	[a]15–10										
	39– 9	145	3– 1	13	1– 2	7	43–12	165	17	5	10
34–75–17	36– 8										
	[a]16– 5										
	20– 3	78	2– 5	10	2–10	16	25– 2	104	17	11	9
34–75–18	24– 5	86									
	40– 0	148									
	64– 5	234	6–12	28	1– 7	10	72– 8	272	21	21	10

B.—*Back of sheet, showing the form for recording the variable fruits found on the trees.*

Variable fruits.	Tree.				Variable fruits.	Tree.			
	15	16	17	18		15	16	17	18
Collared	*8*	*9*		*3*	Ridged, collared, and protruding				
Collared and protruding					Sunken section				
Protruding blossom end					Creased				
Bottle shape					Split				
Raised section					Abnormal shape				
Raised ridge					Brown-rot				
Ridged		*7*	*3*	*17*	Sunburn				
Ridged and collared	*1*								
Ridged and protruding									

[a] Tare to be deducted from total weight.

In some cases, in order to study the fruits after curing, the crops from each tree were kept separate and stored in the packing house for a period of six weeks to two months. After curing, the lemons were again assorted and classified according to their condition and appearance. These studies were made for the purpose of correlating the condition of the freshly picked with that of the cured fruits. During storage the atmospheric conditions in the curing room were maintained as nearly as possible at 70° F. and at 90 per cent relative humidity.

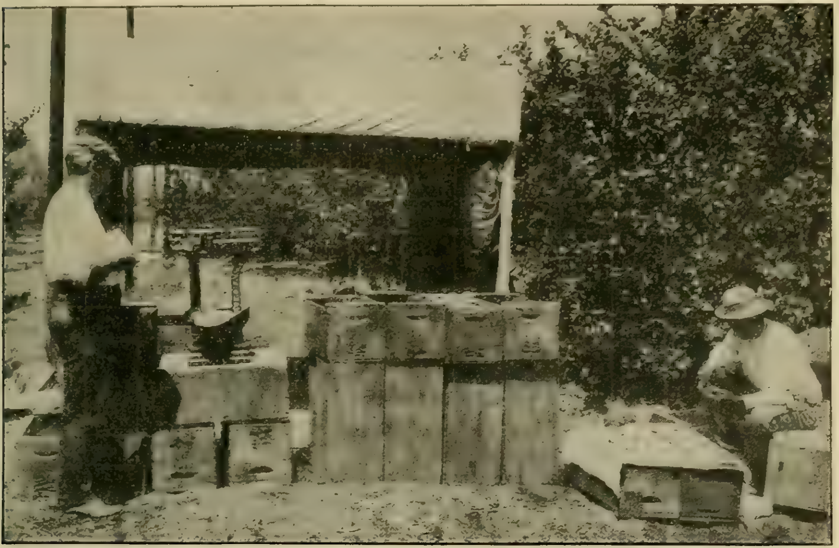


FIG. 2.—Shelter and apparatus used in obtaining performance-record data from lemon trees. The fruit and equipment apparatus were moved out of the shelter temporarily in order to take the photograph used for this illustration.

RECORDING THE DATA.

The data obtained from the study of the fruits picked from each tree at each picking were recorded in special field-note forms, as shown in Table IV. In addition to these data, other notes concerning the individual-tree behavior were made from time to time. As soon as possible after each picking the individual-tree data were transferred to forms providing for a maximum of twelve pickings, or monthly pickings for one year, as shown in Table V. When the complete record for an entire year had been obtained, the data showing the total production for the year, together with accompanying observations, were transferred to a form providing for the bringing together of the data on the individual trees for a period of several years, as shown in Table VIII. Photographs of interesting trees, fruits, flowers, and foliage were frequently taken, in order to fix definitely in the records important phases of tree behavior and fruit characteristics.

TABLE V.—*Performance record of lemon tree number 34–75–16, Eureka strain, showing the weight and the number of fruits of each grade and the number of seeds per fruit produced each month during the season of 1915–16.*

[This record illustrates the form used to assemble the data for each tree for each season. In practice the variable fruits produced by the tree each month are recorded on the back of the form. The weights are given in pounds and ounces. This tree is listed in rank 35 in Tables VI and VIII and in figure 9.]

Date, *1915–16*. Variety, *Eureka*. Strain, *Eureka*. Grower, *National Orange Co.* Location, *Corona, Calif.* Grove, *Chase plantation*. Plat, *34*. Row, *75*. Tree, *16*.

Character of data.	Date, season of 1915–16.												Total or average.
	July 22.	Aug. 28.	Sept. 24.	Oct. 27.	Nov. 24.	Dec. 22.	Jan. 31.	Mar. 1.	Mar. 24.	Apr. 28.	May 27.	June 29.	
Weight of fruits:													
Green grade	2– 7	10–10	16–13	32–11	4–14	3–11	15– 2	19–11	13–14	39– 9	30–10	8– 7	198– 7
Tree-Ripe grade	3– 0	4–12	4–15	4– 5	14–10	33–11	3–12	1– 6	0– 0	3– 1	33– 4	9– 9	116– 5
Cull grade	0– 4	1– 5	1– 0	1–10	1– 4	0– 2	0– 7	0– 7	0–15	1– 2	6–10	10– 8	25–10
Total	5–11	16–11	22–12	38–10	20–12	37– 8	19– 5	21– 8	14–13	43–12	70– 8	28– 8	340– 6
Number of fruits:													
Green grade	10	39	65	129	19	14	55	73	52	145	121	33	755
Tree-Ripe grade	14	22	24	21	60	167	28	9	0	13	154	44	556
Cull grade	2	9	8	13	8	1	2	3	5	7	41	61	160
Total	26	70	97	163	87	182	85	85	57	165	316	138	1,471
Average number of seeds:													
Green grade	10	6	7	10	0	0	0	0	12	17	16	4	6.83
Tree-Ripe grade	8	11	3	3	7	4	5	5	......	5	8	9	6.18
Cull grade	7	5	1	5	6	3	3	5	17	10	8	15	7.08
Total	25	22	11	18	13	7	8	10	29	32	32	28	6.71
Variable fruits:													
Collared	0	0	0	1	1	7	15	17	6	9	16	2	74
Collared and protruding	1	0	0	0	2	0	11	12	3	0	0	1	30
Protruding blossom end	1	0	2	3	1	0	3	6	7	0	1	0	24
Raised ridge	0	0	0	3	0	1	2	0	0	0	2	0	8
Ridged	1	0	2	0	0	0	0	0	1	7	9	0	20
Ridged and collared	0	0	0	0	0	0	0	0	0	0	2	0	2
Ridged and protruding	0	0	0	0	0	0	0	0	1	0	0	0	1
Creased	0	0	2	0	0	0	0	1	0	0	0	1	4
Total	3	0	6	7	4	8	31	36	18	16	30	4	163

An important consideration in obtaining reliable individual-tree performance records is that the data be obtained and recorded in the field, at first hand, while the observations are fresh and clear. In these studies the notes were made during the actual work of picking and classifying the fruits. It frequently happens that in the selection of parent trees as sources of bud wood or in selecting inferior trees for top-working, the final choice is strongly influenced by notes concerning the tree behavior and characteristics of fruiting. The close observation of tree and fruit characteristics during a considerable period of time results in the development of an intimate tree knowledge, which is invaluable in the work of caring for the individual tree and in drawing conclusions as to the value of individual trees and strains for fruit production.

DESCRIPTIONS OF THE IMPORTANT STRAINS.

EUREKA STRAIN.

The Eureka strain is the most productive and valuable in the Eureka variety. It was at first called the Open-Productive strain, and the performance-record data of the trees of this strain were recorded under that name during the entire period of these studies.

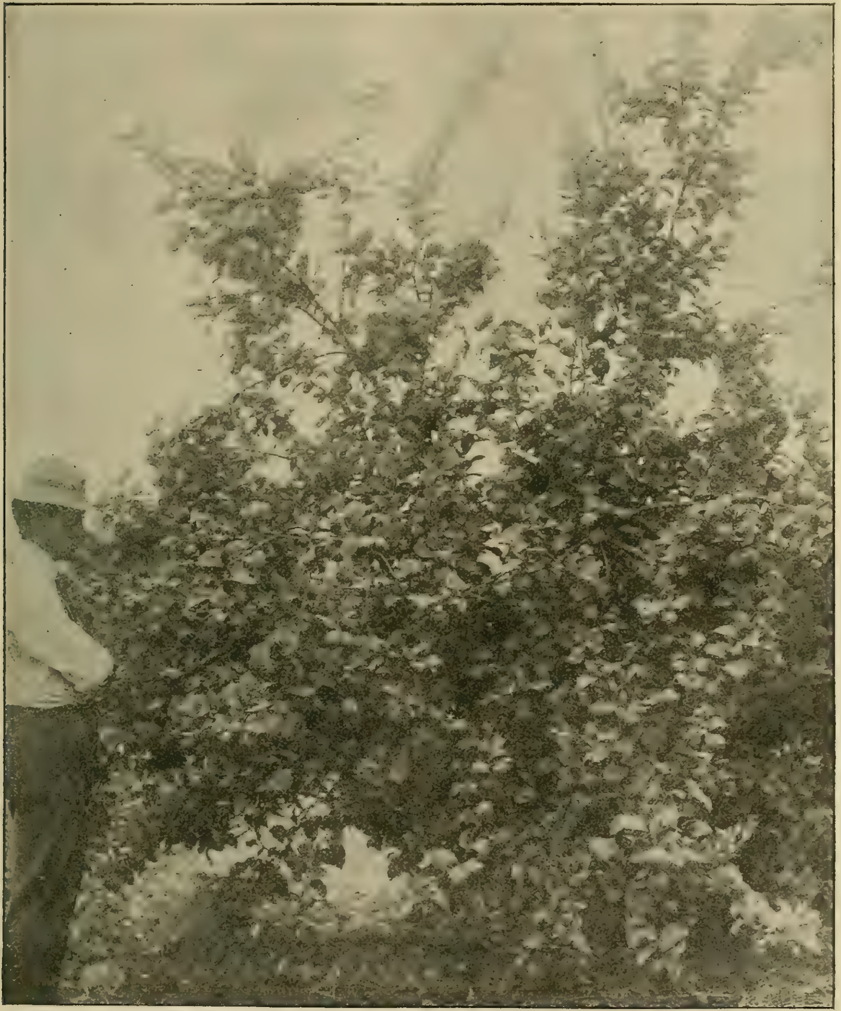


FIG. 3.—A typical lemon tree of the Eureka strain, seven years planted, showing how the heavy load of fruit pulls the branches into drooping positions. The characteristic habit of trees of this strain in setting fruits on the ends of the branches can be seen in this illustration.

The name Open Productive was adopted because of the characteristic habit of growth and the heavy production of the trees in this strain. The characteristics of its trees and fruits are typical of those usually thought of in connection with the trees and fruits of the Eureka variety. For this reason and in the interest of simplicity of nomenclature, the name Open Productive has been dropped and Eureka adopted in its place.

The habit of production of the trees of the Eureka strain in the performance-record plats includes the heavy bearing of high-quality fruits which first set at the ends of the branches, frequently in clusters. As the branches bend down from the weight of the end fruits, others set along the branches in the axils of the leaves until 15 to 20 fruits are sometimes produced by a single branch. The lemons develop in their order from the tip to the base of the branches. The trees have a tendency toward regular production throughout the year, in contrast with the trees of some other strains which tend to bear their crops largely during the fall or the spring or some other limited season. The comparatively heavy production of good commercial lemons regularly throughout all seasons of the year under normal conditions is a very important characteristic of the trees of this strain.

The habit of growth of the trees is open, as shown in figure 1. Usually the fruits first set at the ends of the branches, and as the lemons develop in size and weight the limbs are pulled down in a somewhat drooping position, as shown in figure 3. This condition results in a somewhat open and drooping arrangement of the branches, and, as a result, the trees are opened up to the sun and air. One disadvantage of this habit of tree growth is that the fruits are more likely to be injured by sunburn or extreme climatic conditions than those borne by trees having a dense habit of growth. Few or no suckers are produced by the trees of this strain. The leaves of the trees of the Eureka strain are rather sparse in number, usually of medium size, broadly elliptical and bluntly rounded in shape, with slightly crenate margins and of a deep-green color. The rounded leaves in contrast with the sharply pointed ones of some other strains are a striking and important characteristic of the trees of this strain. The blossoms are perfect, as shown in figure 4, *A*, and the anthers produce viable pollen. Under normal conditions the trees bloom to some extent at all seasons, but most heavily during the spring and fall months. There is no period of the year when blooms and fruits in various stages of growth are not present.

The typical fruits of the Eureka strain, as shown in Plate I, are oblong in shape, medium in size, with smooth texture, thin rind, tender rag, an abundance of juice, and have an average of about seven seeds. Frequently the fruits are slightly ridged. The flesh of the fruits is usually solid and firm. When cured they have a very smooth, satin-like texture and a light-straw color. The receptacle, or button as it is ordinarily called, is usually raised above the surface of the rind somewhat, so that in picking it is possible to sever the stem close to the button without injuring it or the rind with the clippers. Under favorable curing conditions, the button remains green in color and firmly attached to the fruit. If the button is cut or injured in picking, it is liable to turn brown and become detached from the fruit during the curing process.

SMALL-OPEN STRAIN.

The name Small Open, as applied to this strain, is descriptive of the size of the lemons and the habit of tree growth. The main point of difference between this and the Eureka strain lies in the shape and size of the fruits. In shape the fruits are more nearly globular, and they are smaller in size than the typical fruits of the Eureka strain. The habit of growth of the trees is open, like that of the trees of the Eureka strain. In fact, from casual observation little difference can be detected between trees of the two strains, but the difference at once becomes apparent upon close examination of the fruits. Commercially, the difference in the shape of fruits is very important, in that it is much more difficult to make an attractive pack with globular fruits than with the characteristic oblong fruits of the Eureka strain.

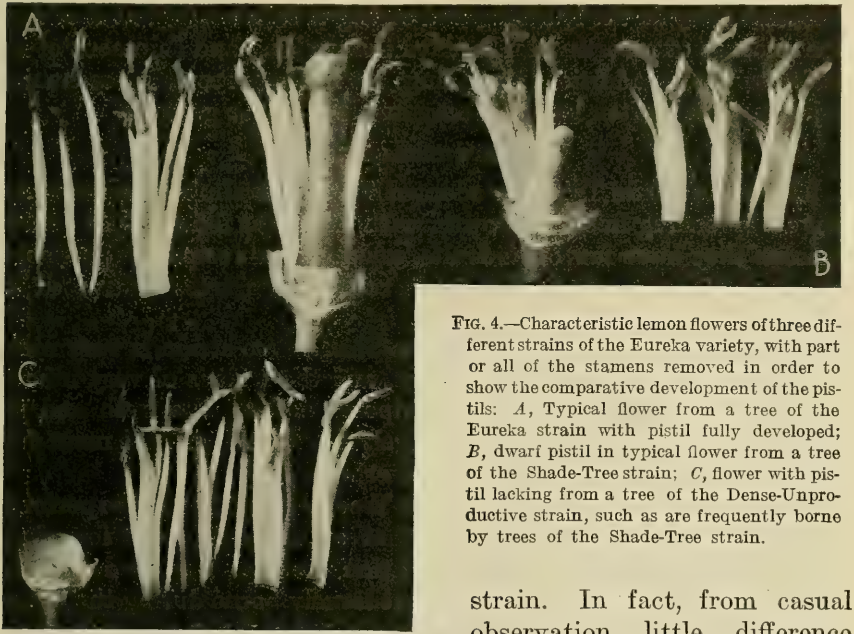


FIG. 4.—Characteristic lemon flowers of three different strains of the Eureka variety, with part or all of the stamens removed in order to show the comparative development of the pistils: *A*, Typical flower from a tree of the Eureka strain with pistil fully developed; *B*, dwarf pistil in typical flower from a tree of the Shade-Tree strain; *C*, flower with pistil lacking from a tree of the Dense-Unproductive strain, such as are frequently borne by trees of the Shade-Tree strain.

The production of the trees of the Small-Open strain in the performance-record plats has been less than that of the trees of the Eureka strain. The season of production is about the same as that of the Eureka strain. The habit of growth is open. The size, shape, number, and color characteristics of the leaves are the same as those of the Eureka strain, so far as observations have been made. The bloom characteristics are very similar to those of the Eureka strain.

The typical fruits are globular, almost spherical in shape, of medium to small size, have a smooth texture, and are without the rather distinct ridges characteristic of fruits of the Eureka strain. They are likely to have a marked depression or crease on the blossom end. The rind is thick, the rag tender, the juice abundant, and the average number of seeds in each fruit is about six.

One of the characteristics of the fruits of this strain develops during curing. As a rule, the fruits cure much more slowly than those of the Eureka strain. The color change takes place very slowly, so that in a lot of fruits of mixed strains it is sometimes necessary to sort out those of the Small-Open strain and retain them in the curing rooms for a longer period than the fruits of some other strains. This condition is unsatisfactory in the handling and curing of lemons, in that it adds to the expense of assorting and delays the packing and shipment of the fruits, while the additional handlings are likely to result in mechanical injuries, which often lead to decay and loss to the growers.

SHADE-TREE STRAIN.

The name Shade Tree was adopted for this strain because the trees have a spreading habit of growth, with luxuriant foliage. At certain seasons they have few or no fruits, making them somewhat resemble ornamental trees grown for shade rather than trees cultivated for their fruits.

The production of the trees of the Shade-Tree strain is very much less than those of the Eureka strain, and the fruit is of very inferior commercial quality, from the standpoint of both the fresh and the cured fruits. The production is largely a seasonal one, the main crop being borne during the fall and winter seasons.

In assorting the fruits of the Shade-Tree strain picked in the performance-record studies it was found that an unusual proportion of the lemons was dark green. This condition was found to be due to the fact that the crops of these trees were largely borne during the season when environmental conditions were favorable for the growth of the fruits and from the fact that the crops were very small in comparison with the size of the trees.

In the beginning of these studies the green fruits of the Shade-Tree strain were included in the first or Green grade, because they were green in color. Later studies, not only of the freshly picked fruits but of the cured lemons as well, brought out clearly the inferior quality of the fruits, as shown by their thick rinds, coarse rag, and scant juice. Notwithstanding the discovery of these facts it was decided to continue the classification of the fruits of the Shade-Tree strain under the Green grade because this characteristic is one which can be unmistakably distinguished in the work of assorting the grades in the orchard. It must be kept in mind that in the case of the crops of the Shade-Tree strain the green color is not synonymous with high grade and quality. In fact, the reverse is true, and if the fruits from these trees had been graded strictly on the basis of the commercial quality of the cured fruits most of them would have been classified as second grade or culls. The results of the studies of the behavior of the fruits of this strain in the curing room emphasizes the importance of this phase of these studies and its desirability in the work of the selection of parent trees as sources of bud wood for propagation.

The habit of growth of the trees is spreading, as shown in figure 5, the main limbs growing in somewhat horizontal positions. Some of the branches, particularly the very vigorous growing vegetative ones, or suckers, have an upright habit of growth. The trees of this strain usually develop more suckers than those of the Eureka strain. The general appearance is that of a wide-spreading shade tree. The leaves are usually large, tapering to sharp points, and profuse, and the margins are usually smooth or slightly wavy and have a deep-green color. Frequently the large leaves are acutely pointed at the

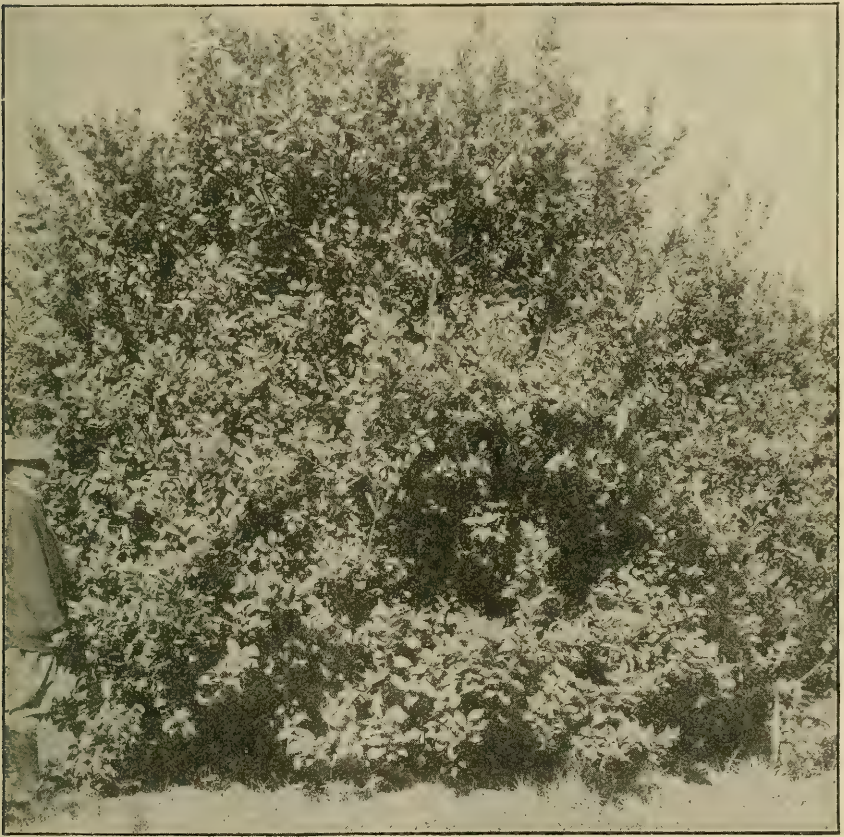


FIG. 5.—A typical lemon tree of the Shade-Tree strain of the Eureka variety, 10 years planted. The trees of this strain grow vigorously and attain great size, but produce only light crops of inferior fruits, which are lacking in juice and acidity.

tips. The characteristically pointed shape of the leaves often assists in the identification of the trees of this strain.

One of the very important tree characteristics of this strain is the large number of imperfect flowers produced. Usually the blooms are very abundant, but most of them fall from the trees. Investigation of this condition established the fact that many of the flowers are imperfectly developed. Usually the pistils in these imperfect flowers are either rudimentary or absent, as shown in figure 4, *B* and *C*. In either case the flowers fall from the trees soon after opening. Furthermore, the anthers of the perfect flowers have frequently been found to contain very little or no pollen. The pollen grains in many instances apparently have such a low vitality that they either do not germinate or, after germinating, they do not complete the processes of fecundation. For this reason the fruits of this strain usually have but few seeds. The imperfect development of the flowers probably accounts in part for the low production of the trees of this strain, and this characteristic is one by which the trees can frequently be identified.

The fruits borne by the trees of this strain, as shown in Plate II are usually oblong, longer than is the case with fruits of the Eureka strain, of large size, coarse and rough in texture, with a strong tendency to ridging. The rind is normally very thick. The rag is coarse and very abundant; the juice is scant, sometimes being almost entirely absent, poor in quality and lacking in acidity; and the seeds average less than two per fruit. The fruits of this inferior strain are distinctly detrimental in every way to the crops in which they occur.

Tree-census studies in the Eureka lemon orchards in southern California have shown that the number of trees of the Shade-Tree strain varies from 10 to 70 per cent. On the average, 25 per cent of the trees in these orchards were found to be of this strain. These trees, owing to their vigorous vegetative condition, are well adapted to top-working. Performance-record studies of such top-worked trees have shown that under favorable climatic and cultural conditions they can be brought to profitable production of good fruit within three years.

The Shade-Tree strain is one of the most important in the Eureka variety, from the fact that the trees, flowers, and fruits have unmistakable characteristics and also owing to its extensive occurrence in many Eureka orchards. Its elimination in established orchards, through top-working with selected buds from trees of the Eureka strain, will increase and improve the production in many orchards not less than 25 per cent. Its propagation in the future can be avoided largely through bud selection from superior performance-record trees of the Eureka strain.

DENSE-UNPRODUCTIVE STRAIN.

The trees of the Dense-Unproductive strain are the least productive of any of those of the Eureka variety under observation in the performance-record plats, and the light yield of these trees is coordinated with a correspondingly inferior quality of the fruits. In many ways they resemble the trees of the Shade-Tree strain. The crops of fruit are borne at about the same season, but the habit of growth of the trees, instead of being spreading, is more erect and dense, as shown in figure 6.

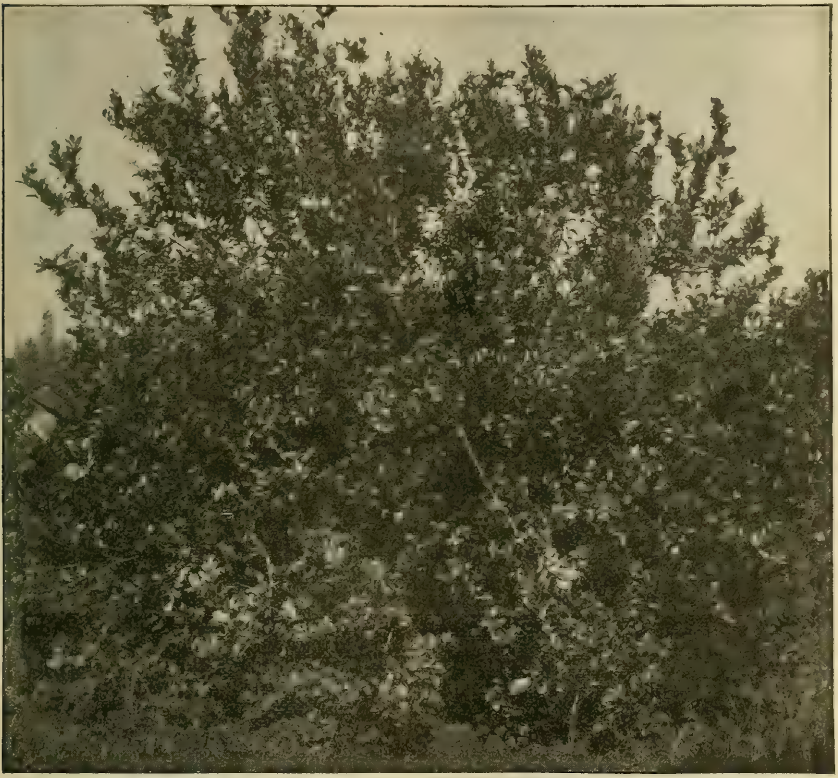


FIG. 6.—A typical lemon tree of the Dense-Unproductive strain of the Eureka variety, 10 years planted The vigorous and dense vegetative characteristics and lack of fruit are very marked.

The trees usually have a large amount of vigorous vegetative growth, or suckers. The leaves are usually not as large as those of the Shade-Tree strain, but in general their shape and color are very similar. The number of leaves produced by the trees of this strain is greater than is the case with the trees of the Shade-Tree strain. The percentage of imperfect flowers of the trees of this strain is larger than in those of the Shade-Tree strain. This abnormal condition of the blossoms is partly responsible for the light yield of fruits of the trees of this strain. The pistils are often small, rudimentary, or lacking, as is shown in figure 4, *C*. The pollen of the flowers is scant in quantity and of low vitality. This condition accounts for the few seeds found in the fruits, as a rule. Occasionally, in a perfect flower the anthers develop an abundance of viable pollen, in which case the fruits set the normal number of seeds.

The fruits, as shown in Plate III, are oblong, of large size, coarse in texture, and have very thick rinds. The rag is tough and abundant; the juice is scant, of poor flavor, and low acidity; and the fruits have an average of 2¼ seeds.

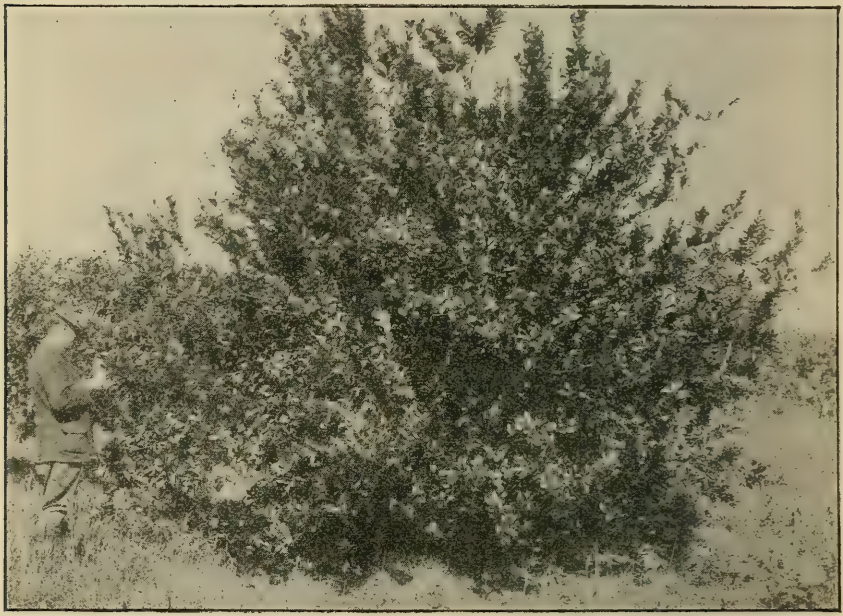
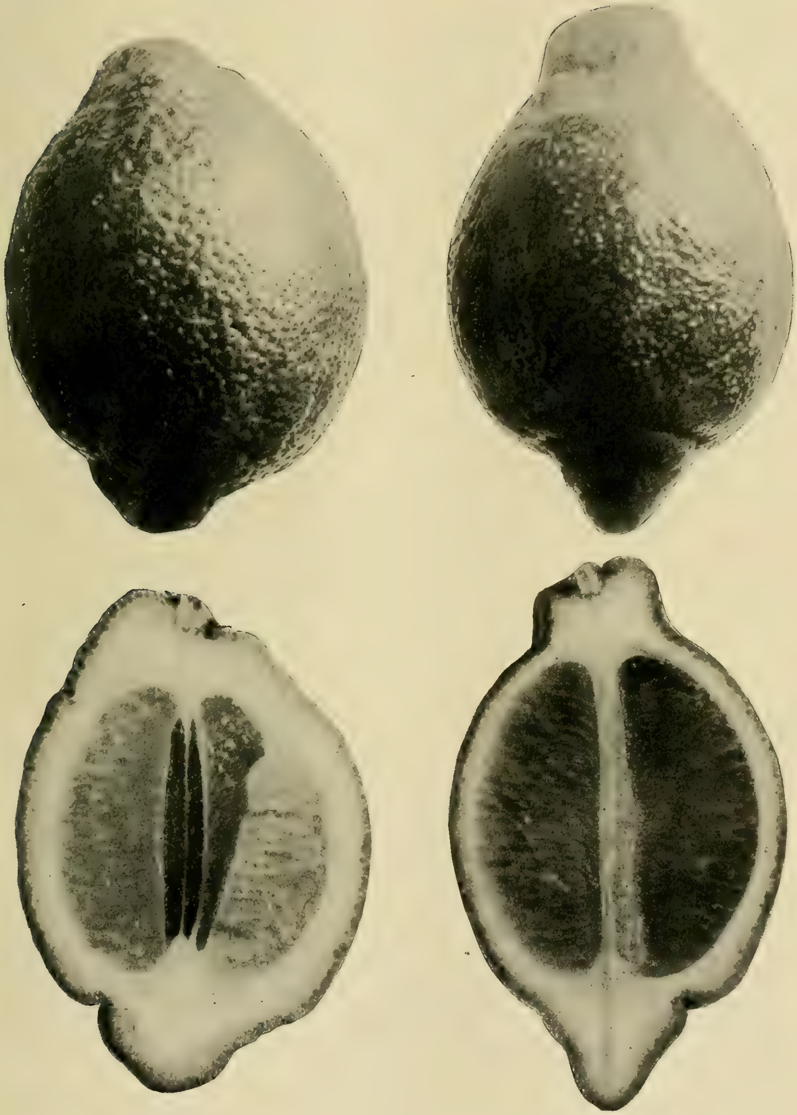


FIG. 7.—A typical lemon tree of the Pear-Shape Eureka strain, 10 years planted. The trees of this strain develop many small branches, giving them a dense appearance. They produce smooth, pear-shaped fruits with long necklike stem ends which are objectionable in packing the fruits for the market.

PEAR-SHAPE STRAIN.

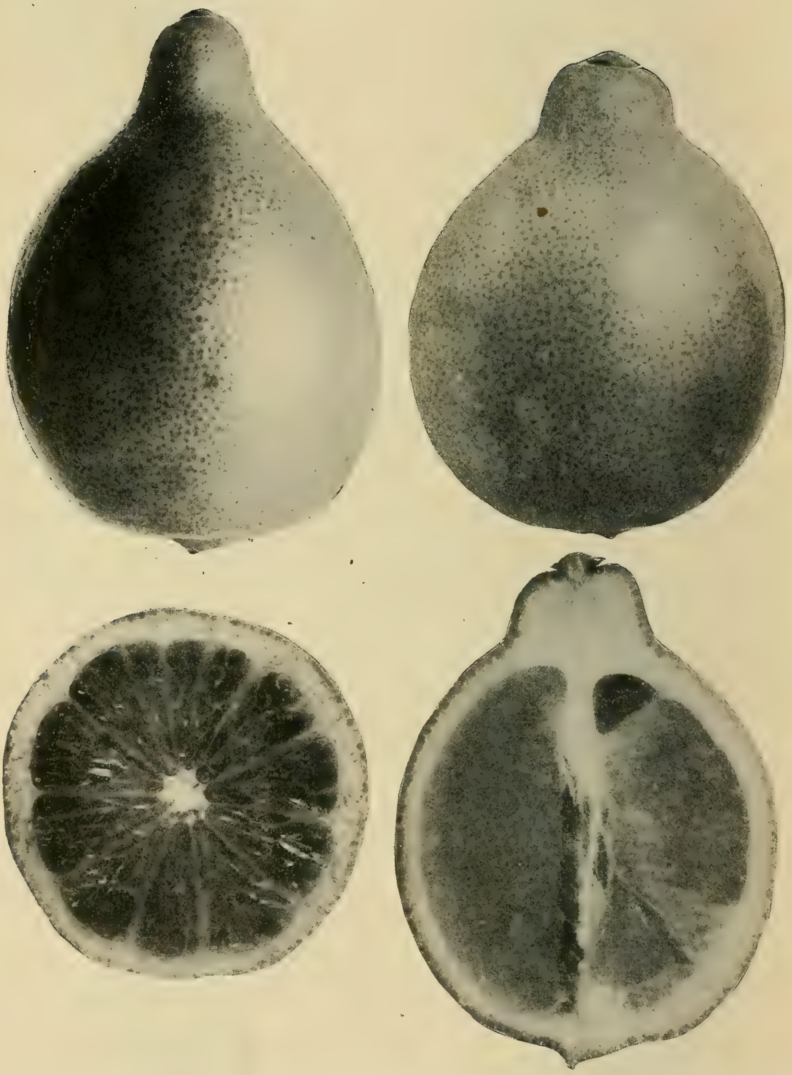
The Pear-Shape strain was given a name descriptive of the shape of the typical fruits. While the trees and fruits differ in many characteristics from those of the other strains, the peculiar shape of the fruits is especially marked. These fruits must be clearly understood to be normal and healthy ones and not the diseased, undeveloped, or misshapen fruits often borne by trees suffering from unfavorable cultural conditions.

The season of production of the fruits by the trees of the Pear-Shape strain is similar to that of trees of the Eureka strain and is more or less regular throughout the year. The yield is usually medium, but on account of the peculiar bottlelike shape of the lemons it is of inferior commercial value.



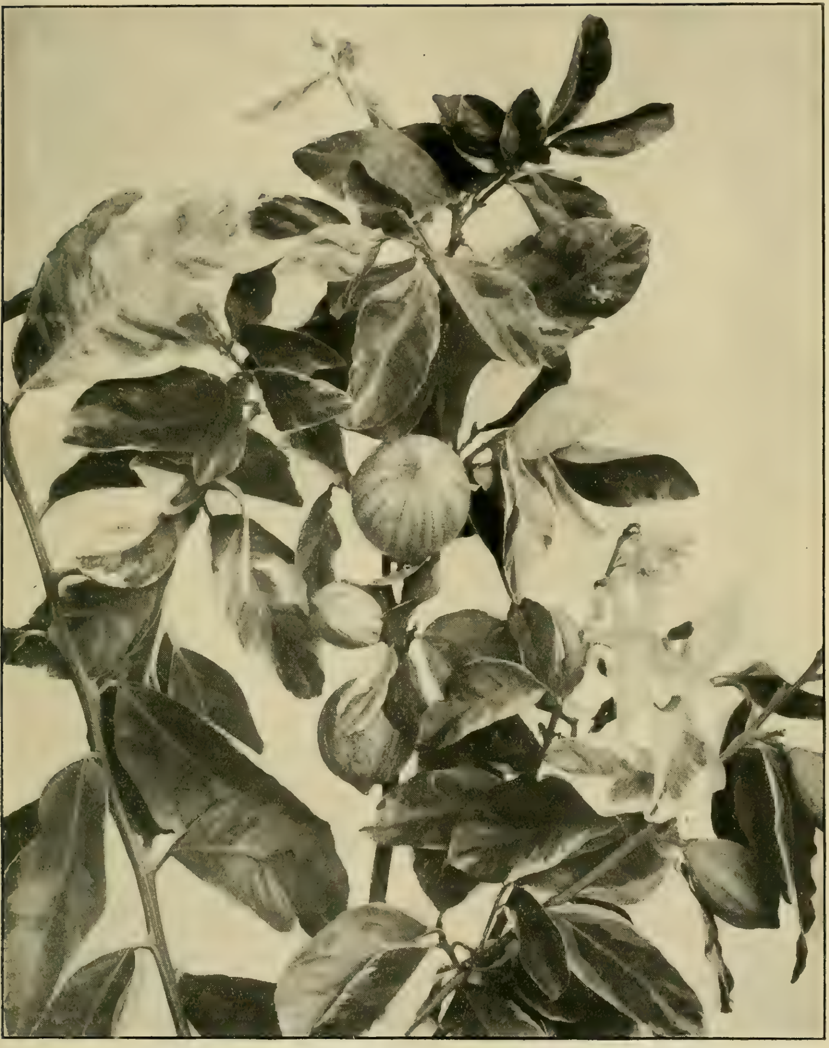
Two Typical Lemon Fruits of the Dense-Unproductive Strain of the Eureka Variety.

About three-fourths natural size.



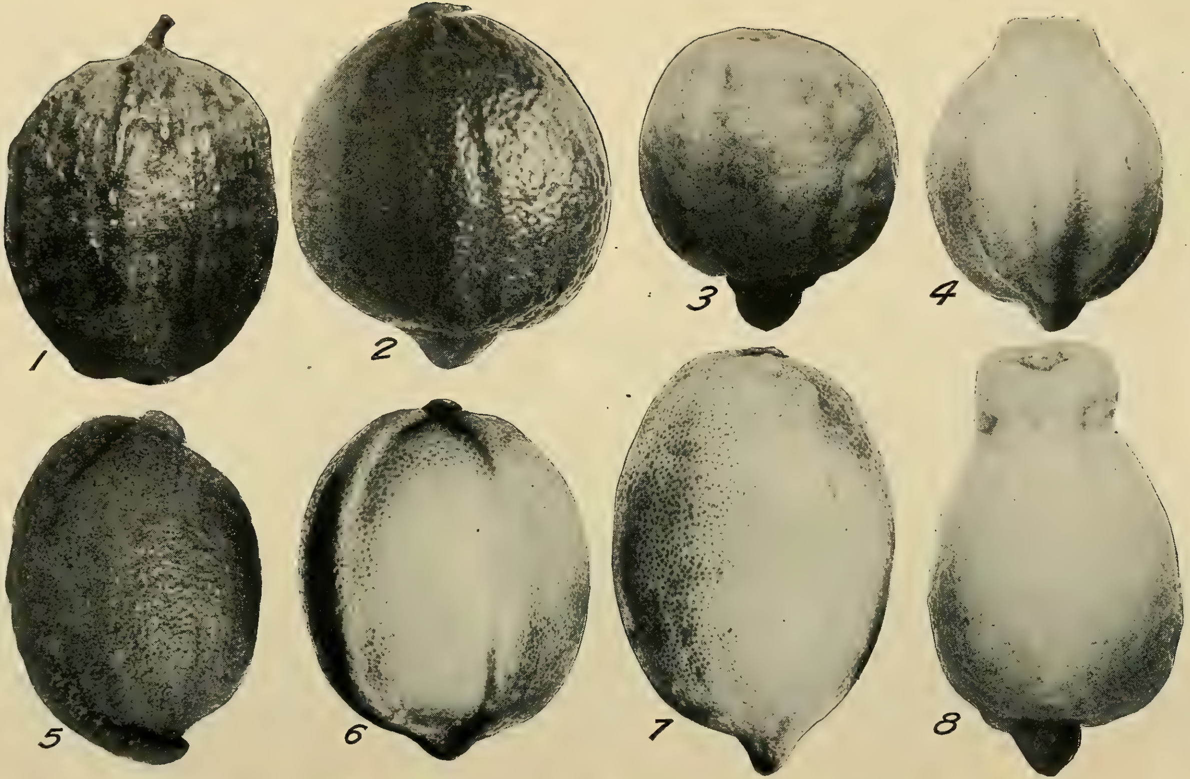
TWO TYPICAL LEMON FRUITS OF THE PEAR-SHAPE STRAIN OF THE EUREKA VARIETY.

These fruits have smooth texture, long-necked stem ends, and thin rinds, and are poorly adapted for making a good commercial pack. About four-fifths natural size.



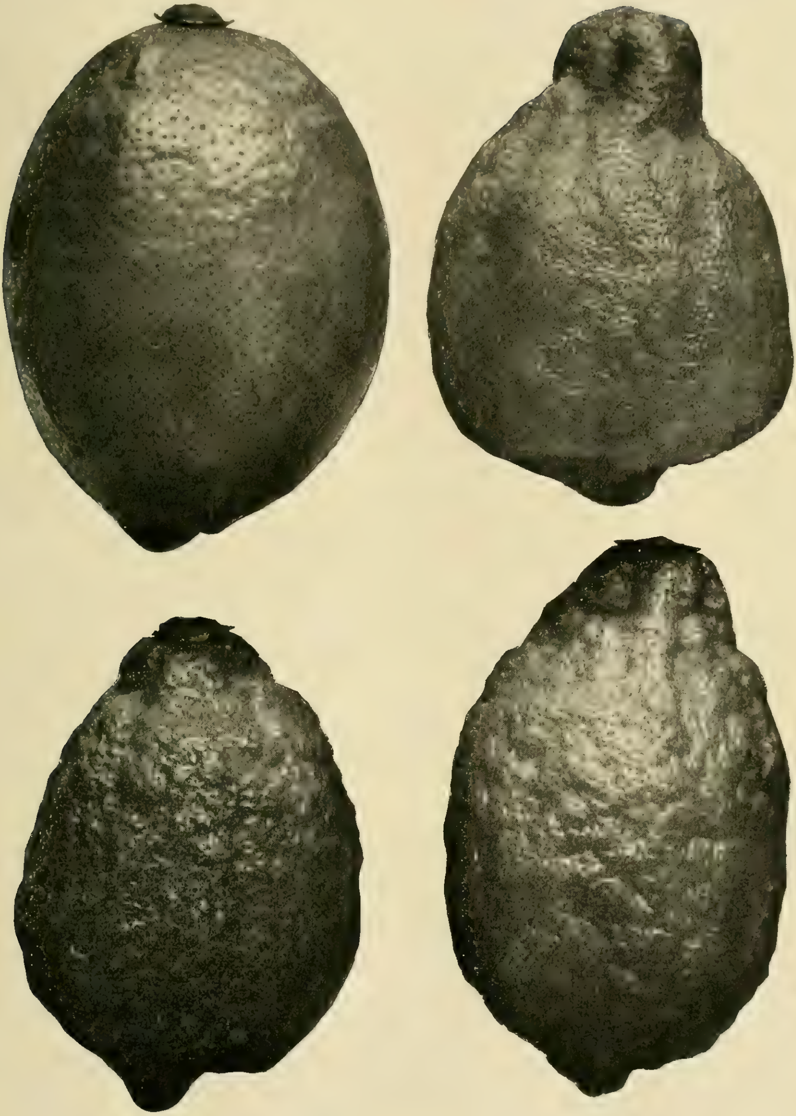
BRANCHES AND FRUIT FROM A LEMON TREE OF THE VARIEGATED STRAIN OF THE EUREKA VARIETY.

The characteristic markings on the leaves, fruit, and young wood (see branch at left) are here shown. At the right is a twig with leaves which are entirely straw colored, bearing a terminal blossom.



TYPICAL FRUITS FROM A LEMON TREE OF THE SPORTING STRAIN OF THE EUREKA VARIETY.

Variations in shape, texture, and other characteristics are here shown: 1, Corrugated; 2, round, ridged, and protruding blossom end; 3, round, rough, and protruding blossom end; 4, ribbed; 5, ridged with coarse raised section; 6, sunken section; 7, white section; 8, collared and protruding blossom end. About two-thirds natural size.



A TYPICAL EXAMPLE OF UNDESIRABLE FRUITS BORNE AS LIMB VARIATIONS ON A EUREKA LEMON TREE.

The three coarse fruits were from two limb sports produced by a tree bearing normal, smooth Eureka lemons on all its other branches. About four-fifths natural size.

The trees, as illustrated in figure 7, are very finely branched; so much so that they can quickly be identified by the masses of small branches and their rather brushlike appearance. The leaves are usually small in size, ovate in shape, with sharply pointed tips, abundant in number, and of a rather light green color. The flowers are perfect and similar to those of the Eureka strain except that the pollen is usually small in quantity and of low vitality.

The typical fruits of the Pear-Shape strain, as shown in Plate IV, are conspicuously and markedly different from the fruits of the other strains. The lemons are oval or pear shaped, with frequently elongated or bottle-necked stem ends, and of small to medium size. The rind is thin and of a very smooth, fine texture. The rag is tender, and the juice is abundant and of low acidity. The fruits average about two or three seeds.

DENSE-PRODUCTIVE STRAIN.

The trees of the Dense-Productive strain differ from those of the Eureka strain mainly in their habit of growth and density of foliage. These trees have a dense appearance, owing to the larger number of branches and leaves, and the fruits are largely covered by the protecting foliage. The leaves are of medium size, oval shape, obtuse, abundant in quantity, and from deep to dark green in color. The flowers closely resemble those of the Eureka strain.

The fruits are oblong, medium in size, of smooth texture, and with little or no tendency to ridging. The rind is medium thick, the rag is tender, the juice is abundant and of high acidity, and the fruits average between six and seven seeds.

Owing to the habit of growth of the trees and the density of foliage, the fruits are less likely to climatic injury, or sunburn, than those of the Eureka strain. This condition makes up in part for the somewhat lower production of the trees of this strain as compared with those of the Eureka strain in the performance-record plats.

VARIEGATED STRAIN.

In the tree-census studies of Eureka lemons in the orchard in which the performance-record studies were carried on, branches bearing one or more variegated fruits and entire trees producing crops of variegated lemons were discovered. On account of the striking color contrasts of both the fruits and the foliage, representative fruits, branches, or trees of the Variegated strain were easily located.

The habit of growth of the trees of the Variegated strain is open, the production of fruits is good, and the trees bear fruits during all seasons of the year. The bark of the young branches is variegated with fine stripes of shades of green and straw color (Nos. 31 L, 29''', 25''b, and 21'd of Ridgway's Color Standards, edition of 1912). The leaves are oval in shape, obtuse, of medium size, fairly abundant in number, and variegated in color, as shown in Plate V. The white and green sections of the leaves occur in areas of variable size and shape, in some cases the leaves being almost wholly green, while in others they are nearly or entirely white. The flowers are perfect and apparently like those of the Eureka strain.

The fruits are oblong in shape, of medium size, and rough or ridged in texture. The rinds are thin. The rag is tender, and the juice is abundant and somewhat lacking in acidity. The seeds are similar in number to those of fruits of the Eureka strain.

The fruits have a striped appearance, usually with alternate green and white areas. Accompanying this appearance there is usually a ridged condition which accentuates the striped appearance. The ridges are usually green and the intermediate spaces white. Not only are the leaves and fruits striped or variegated, but the bark of the branches on the trees of this strain also has a similar appearance.

The rough texture of the fruits, their variegated appearance, and the thin rinds, which are liable to split, makes them of inferior commercial value. Many citrus growers in California have taken bud wood from the variegated trees in the performance-record plats in order to grow one or more trees for ornamental purposes.

The chief value of this striking variation lies in its occurrence as single-fruit, branch, and entire-tree variations of the Eureka variety, thus demonstrating its origin from bud variations.

SPORTING STRAIN.

In one instance in the performance-record plats, and occasionally throughout the 250-acre grove of Eureka lemons in which these plats are located, trees have been found in vigorous vegetative condition with many branch variations, as shown by both the vegetative and fruit characteristics. In a Sporting tree in one of the performance-record plats, different branches, all grown from a single bud, produce typical fruits of all of the strains under observation and several minor variations of the Eureka variety. Plate VI shows specimens representing several strains and variations borne on one tree grown from a single bud. A similar condition of variability has been observed frequently, so it seems apparent that there exists a strain of the Eureka lemon which breaks up into many variations having very diverse characteristics. Other trees are often found in which only one or two branches are producing fruit of some strain or variation different from the rest of the tree, as illustrated in Plate VII.

The trees of the Sporting strain vary in productiveness and season of production corresponding to the proportions of the various strains produced by them. If the productive strains are dominant, the trees are productive, while if the unproductive strains are most evident the trees are unproductive. As a rule, the trees are comparatively large and show a very vigorous vegetative condition, as illustrated in figure 8. Usually they develop a spreading habit of growth. The leaf, flower, and fruit characteristics are similar to those of the strains represented in the trees.

It seems probable that these large fine-appearing trees of the Sporting strain are responsible for some of the variability of varieties existing in the established lemon orchards of California. Their handsome appearance naturally attracts the eye of the bud cutters and their vigorous vegetative growth makes it possible to secure a large number of buds from each tree.

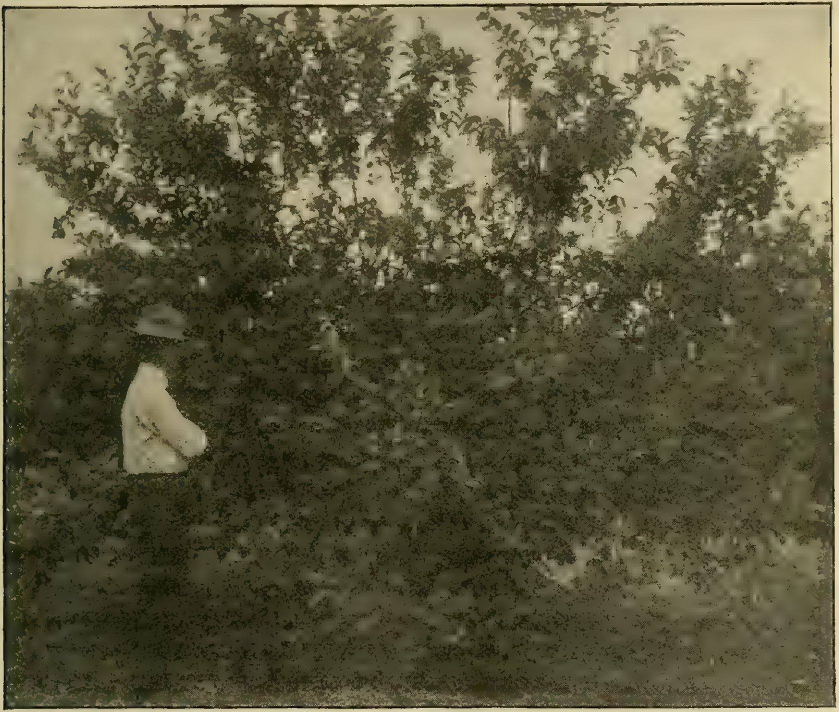


FIG. 8.—A typical lemon tree of the Sporting strain of the Eureka variety, seven years planted. This tree is mostly made up of branches showing the characteristics of the Shade-Tree strain, but other strains including the Variegated, Pear Shape, Eureka, and Small Open are represented.

This strain is very undesirable, not only from the standpoint of the mixture of fruits, necessitating additional care in assorting them during packing, but also from the danger of the trees being used as sources of bud wood by inexperienced propagators.

LESSONS TAUGHT BY THESE INVESTIGATIONS.

The performance-record studies of individual trees of the Eureka lemon have been particularly interesting, for the reason that the frequent pickings have made possible almost continuous systematic observations throughout the entire year.

The performance-record studies reported in this bulletin have been carried on during a period when the propagation of lemon trees has been particularly active. The lemon industry has expanded rapidly during this time, and the information gained in the course of these investigations has been utilized generally in the propagation of the trees for the large new plantings. A very large number of buds from the superior trees of the Eureka strain in the performance-record plats have been furnished to propagators. These buds from the individual parent trees have been kept separate, so that each progeny can be traced at any time from the orchard planting to the parent trees. Not only have a great number of buds been taken from the best performance-record trees for propagation commercially, but buds from some of the poorest trees have also been propagated at the same time, in order to compare under orchard conditions the behavior of the progenies of the most desirable with those from the undesirable parent trees. The active interest shown by lemon growers in these studies has given the work an additional interest.

The early fruiting of the young trees propagated from the select trees in the performance-record plats permits comparatively quick opportunities for measuring the results of bud selection. The uniformly heavy and superior production of the progenies from the desirable parent trees and the light production of inferior fruits of the progenies from the undesirable parent trees have demonstrated conclusively the importance of bud selection in lemon propagation. The information gained from these investigational individual-tree performance-record data, the demonstrations of the important results of bud selection, and the related observations made during the course of these studies have been the basis upon which have been developed the present improved methods of practice in California in keeping individual-tree records, in the selection of undesirable trees in established orchards for top-working or removal, and in the choice of superior trees as sources of bud wood for propagation.

It is desirable to emphasize the fact that the conclusions presented here have not all been derived from a study of the performance-record data alone. Some phases of tree and fruit characteristics can not be recorded in figures or reproduced by illustrations. These indefinable characteristics are of importance and usually are perceived only by those who have a natural aptitude for this kind of work. The intimate tree knowledge essential for this work is gained only by almost daily and continuous contact with the trees and fruits. The instinct enabling the observer to distinguish one strain of tree or fruit from another and to select the best from among many individuals is almost, if not equally, as important as the actual tree records themselves.

Within some of the strains are marked variations of importance commercially, but not so striking as the variations which distinguish the strains themselves. These individual-tree differences in the strains should be taken into account by the performance-record keeper and this knowledge utilized in the selection of trees for top-working or for use as sources of bud wood.

Fortunately there is a marked correlation between the quantity and quality of the fruits produced by the individual trees of the different lemon strains. The trees bearing the most lemons usually produce the best commercial fruits. In other words, the trees having the heaviest crops frequently develop the largest proportion of lemons of the first grade, as shown by their color, shape, size, texture, thickness of peel, juiciness, acidity, and the flavor of the juice. Usually the most productive trees show the fewest marked variations in fruits from the type of the strain to which they belong. This condition is fortunate in that it enables the grower to form a reliable conception of the value of the fruits of the individual trees from their production records. A similar correlation was found in the studies of the individual-tree production of the various strains of the Lisbon lemon, the Washington Navel orange, the Valencia orange, and the Marsh grapefruit.

PRESENTATION OF DATA.

The diagrams and tables presented herewith in summarizing the studies on the Eureka lemon variety have been prepared from individual-tree performance records of 117 trees in a single plat in a 750-acre citrus orchard near Corona, Calif. These trees are in a section of the orchard which was planted in the spring of 1904, nothing except a few crops of winter barley having been grown there previously. Records were begun on 111 of the trees in July, 1911, and 6 more near-by trees were added to the record plat in December, 1912. The original plat selected for this study included 116 trees, but 5 of them were badly injured, so that their records were not comparable with those from the other trees in the plat. Among the 117 trees included in this study there are typical examples of 6 of the 8 most important strains of the Eureka variety, as follows: 76 Eureka, 17 Shade Tree, 10 Small Open, 10 Dense Unproductive, 2 Pear Shape, and 2 Dense Productive.

Individual-tree performance records have been secured in the same orchard on 135 additional Eureka trees. However, as these records have not been made for as long a period as the 117 trees in the original plat, the presentation and consideration of data in this bulletin will be confined to the records of the 117 trees.

The average annual crop of each of these trees for the 6-year period from July, 1911, to June, 1917, inclusive, is shown in Table VI. The percentage of the most desirable fruit of the Green grade, produced by each tree is also expressed, being figured on the basis of the weight of the crop. The proportion of variable fruits, by number, is shown, as well as the average number of seeds per fruit. In the performance data the number of split fruits have been recorded, as have those showing brown-rot and sunburn, but such fruits are not included in the class of variable fruits. In this table the trees are ranked arbitrarily according to their average annual crops by weight, without regard to the grade or quality of their fruit or its uniformity. This basis of classification was adopted as the simplest and most satisfactory one for this purpose, but its character is such that the rank of the trees as listed does not necessarily give a true index of their actual relative value. It would be impracticable to attempt to rank all the trees of any large plat on such a basis, though it is usually quite possible to select the few of the most desirable individuals and those most undesirable. It is interesting to note that of the 62 highest producing trees listed in this table all but three are of the Eureka strain.

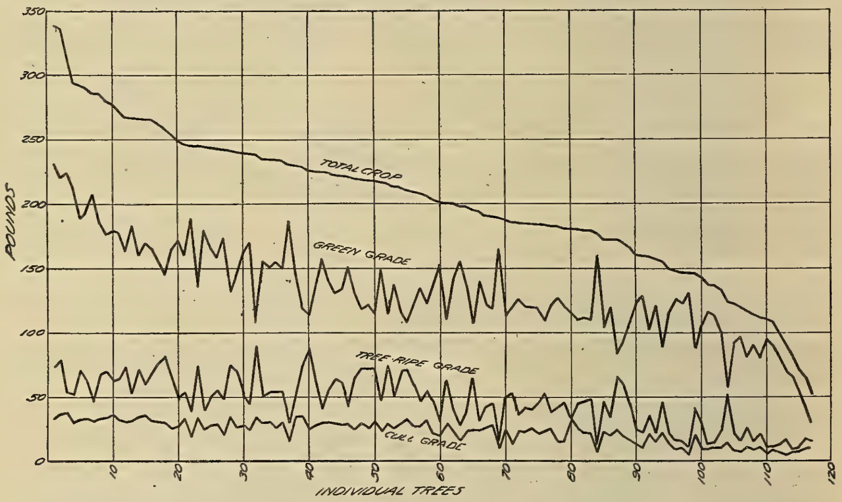


FIG. 9.—Diagram showing the average annual total crops and the production by the three commercial grades from the individual trees in the investigational performance-record plat of Eureka lemons during the 6-year period from July, 1911, to June, 1917, inclusive.

In most cases where summaries are shown, the average or percentages are figured from totals for the period indicated, and not from averages or percentages previously computed.

A graphic representation of the variations in weight of the average annual crops of all the trees in the Eureka lemon plat is presented in figure 9. The trees are arranged from left to right in the order of their rank, on the basis of their total crops as given in Table VI, and the production of fruits of the Green, Tree-Ripe, and Cull grades by each tree is shown.

Table VII represents the main portion of the investigational plat of Eureka lemon trees, showing by symbols the position of each tree and the strain to which it belongs and also indicating its rank in fruit production, by weight, as given in Table VI. The designation of rows and tree numbers serves to show the distribution of the trees of the different strains and ranks throughout the plat.

TABLE VI.—*Summarized statement of the average annual production of 117 individual lemon trees of the Eureka variety for which detailed performance records were obtained for the 6-year period from July, 1911, to June, 1917, inclusive.*

[Detailed performance records of the trees marked with an asterisk (*) are shown in Table VIII. The trees marked with a dagger (†) were added to the plat in December, 1912. The number of variable fruits is computed from data for the 3-year period from July, 1914, to June, 1917, inclusive. Records of the number of seeds per fruit were for the 5-year period from July, 1911, to June, 1916, inclusive.]

Rank.	Strain.	Tree designation.	Average annual crop production.				Seeds per fruit.
			Weight.	Number.	Green grade.	Variable fruits.	
			Pounds.		*Per cent.*	*Per cent.*	
1	Eureka	*34-73- 7	338.24	1,479.83	68.4	11.4	6.83
2	do	34-74-21	336.97	1,482.33	65.6	8.0	7.72
3	do	34-73- 6	315.49	1,383.83	71.1	13.6	5.34
4	do	34-73-17	293.54	1,311.17	71.9	11.2	7.10
5	do	34-74-22	291.51	1,319.67	64.5	9.1	6.32
6	do	†34-73-21	289.64	1,347.60	66.9	10.5	6.88
7	do	34-73-13	285.77	1,273.67	72.5	10.3	6.60
8	do	34-74-20	285.74	1,302.17	64.8	8.5	6.34
9	do	*34-76-23	280.01	1,258.33	63.1	6.0	8.62
10	do	34-76-21	277.64	1,259.67	64.3	6.0	8.39
11	do	34-75-12	272.85	1,211.83	64.8	6.7	7.30
12	do	34-77-19	267.06	1,253.33	60.8	3.6	7.31
13	do	34-74- 7	266.40	1,176.50	68.8	8.8	6.90
14	do	34-75-21	266.03	1,203.17	60.0	6.2	6.77
15	do	34-75-20	265.97	1,157.50	63.8	7.8	8.24
16	do	34-76-13	265.96	1,211.50	62.1	6.7	7.98
17	do	*34-77-16	262.42	1,221.33	59.0	4.7	7.86
18	do	34-77-17	257.95	1,219.33	56.5	4.3	7.31
19	do	34-76-20	253.65	1,145.50	64.2	4.4	6.96
20	do	34-73-10	249.14	1,116.67	68.9	10.2	6.10
21	do	34-74-16	246.41	1,143.83	64.4	7.7	6.75
22	Small Open	*34-73- 8	244.88	1,037.00	77.0	20.5	4.16
23	Eureka	34-77-18	244.57	1,168.83	55.1	3.6	8.14
24	do	34-73- 9	243.50	1,050.33	73.6	11.7	5.85
25	do	34-73-12	243.14	1,098.17	68.0	12.1	5.34
26	do	*34-74-10	241.89	1,067.67	65.2	8.9	7.63
27	Dense Productive	*34-73-19	241.39	1,064.00	71.4	13.3	5.97
28	Eureka	34-77-22	240.90	1,177.50	54.6	3.1	8.18
29	do	34-75-11	239.72	1,087.67	60.0	8.3	7.93
30	do	34-74-14	239.24	1,051.17	67.6	8.7	4.60
31	do	34-73-14	238.39	1,049.83	71.2	11.5	5.71
32	do	34-77- 3	238.35	1,147.67	48.0	3.8	7.85
33	do	34-74-18	234.54	1,055.17	65.7	7.5	3.97
34	do	34-75-18	234.15	1,063.50	64.3	9.5	6.64
35	do	*34-75-16	233.80	1,055.00	66.1	9.5	4.37
36	do	34-76-22	233.73	1,078.67	64.0	5.9	8.80
37	do	34-73-11	230.17	940.67	81.2	15.5	4.86
38	do	34-74- 6	228.96	1,052.17	63.0	10.3	6.22
39	do	34-77-21	228.02	1,107.00	52.0	4.3	7.83
40	do	34-77-12	225.26	1,043.50	50.3	4.4	8.75
41	do	34-75-22	224.95	1,015.83	60.1	7.5	5.98
42	do	34-73-18	224.80	1,065.83	69.8	13.7	6.12
43	do	*34-76- 8	223.89	1,036.33	62.0	6.7	7.67
44	do	34-76-15	221.80	1,034.50	58.6	7.1	9.09
45	do	34-76-18	221.51	1,040.83	60.2	4.5	7.71
46	do	34-74-19	220.44	977.67	68.2	9.7	4.39
47	do	34-75- 2	218.47	997.00	59.3	5.8	7.76
48	do	34-76-17	218.23	1,018.67	53.9	5.4	7.22
49	do	34-77-15	217.55	1,025.17	55.8	4.8	7.43
50	do	34-77- 8	217.32	1,058.17	52.4	4.7	8.62
51	Small Open	34-73- 1	216.50	954.33	68.1	9.3	6.98
52	Eureka	*34-77-11	215.36	1,030.83	52.6	4.4	9.82
53	do	34-75-19	213.10	963.00	64.7	8.7	7.25
54	do	34-77-20	213.02	1,024.83	54.3	4.4	9.07
55	do	34-76-19	210.25	1,022.50	51.1	5.5	7.98
56	do	34-76-16	208.89	977.50	58.9	4.9	7.56

TABLE VI.—*Summarized statement of the average annual production of 117 individual lemon trees of the Eureka variety for which detailed performance records were obtained for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank.	Strain.	Tree designation.	Average annual crop production.				Seeds per fruit.
			Weight.	Number.	Green grade.	Variable fruits.	
			Pounds.		*Per cent.*	*Per cent.*	
57	Eureka	34-74-17	207.28	945.67	64.3	7.2	4.88
58	do	34-75- 5	205.56	970.00	59.0	9.3	7.86
59	do	34-76-12	202.90	883.83	66.5	7.5	7.91
60	do	*34-74- 8	201.24	834.00	75.7	9.8	6.23
61	do	34-76- 5	200.14	980.50	54.5	5.7	7.23
62	do	34-76-10	199.28	873.50	69.7	8.2	6.67
63	Shade Tree	*34-74-15	197.53	804.17	78.5	13.8	5.10
64	Eureka	34-76-11	197.42	870.33	69.4	6.3	7.75
65	do	34-77- 7	194.76	926.83	54.4	5.6	9.02
66	Dense Productive	*34-73-16	193.72	897.67	71.6	11.2	7.05
67	Eureka	34-75-36	190.05	866.33	64.1	8.2	7.18
68	do	34-75- 3	189.68	891.33	62.0	11.3	6.35
69	Shade Tree	34-74-56	188.16	751.33	87.2	12.9	1.11
70	Eureka	34-75- 7	187.15	845.17	60.1	7.0	6.64
71	Pear Shape	*34-74-11	184.89	837.17	63.9	50.4	1.77
72	Eureka	*34-73- 5	184.64	842.33	68.0	15.8	6.19
73	do	34-73- 4	183.71	826.17	65.3	15.1	6.67
74	do	34-75- 9	183.44	837.67	64.9	6.1	7.91
75	do	34-75- 4	183.42	828.17	64.0	8.0	7.82
76	do	34-77- 9	183.42	860.00	58.9	2.9	7.83
77	do	34-75-10	182.20	820.67	65.9	7.9	7.99
78	Small Open	34-77-13	182.18	803.50	69.4	6.9	6.49
79	do	34-74- 2	180.49	804.33	65.9	8.9	2.41
80	Eureka	34-74- 9	180.27	842.17	64.2	10.6	5.95
81	Small Open	*34-75- 8	179.22	831.00	61.0	6.4	7.77
82	Eureka	34-75-17	178.54	823.83	62.3	6.4	4.70
83	do	34-76- 9	178.49	820.33	61.3	6.2	7.55
84	Shade Tree	34-74- 4	176.43	701.83	89.7	13.2	0.67
85	Eureka	34-76- 7	171.88	804.83	59.7	7.5	7.80
86	Small Open	34-73- 2	171.23	755.17	69.4	7.9	7.92
87	Eureka	34-77- 5	171.22	847.00	48.5	4.9	8.27
88	do	*34-77- 6	169.07	803.50	54.7	6.9	8.32
89	Small Open	34-76-14	165.86	847.00	64.6	8.9	6.87
90	Shade Tree	†34-67-12	160.28	671.20	76.8	15.6	1.92
91	do	34-73-15	158.93	652.00	80.2	20.6	1.35
92	Small Open	34-74- 3	158.06	702.00	64.4	9.6	4.72
93	Shade Tree	*34-75-13	156.72	659.00	77.4	15.4	5.28
94	Small Open	34-76- 6	154.61	760.67	56.4	7.7	6.92
95	Dense Unproductive	*34-74-12	148.29	621.17	77.4	16.2	4.43
96	Shade Tree	34-74-54	147.55	617.00	84.2	16.2	0.97
97	do	34-74-47	146.53	604.00	83.2	22.2	1.59
98	do	34-74- 5	145.72	568.50	89.6	17.0	0.88
99	Small Open	*34-75- 6	145.61	693.83	58.4	8.5	6.38
100	Dense Unproductive	34-77-14	142.29	592.83	73.5	12.7	2.05
101	Shade Tree	34-74-51	136.60	599.17	84.9	17.1	1.16
102	do	*34-74-13	136.14	553.33	82.6	18.0	0.98
103	do	34-75-14	132.74	554.00	75.2	14.2	1.48
104	Pear Shape	*34-77-10	122.55	605.33	46.6	49.7	2.95
105	Shade Tree	34-75-15	121.08	491.17	76.2	16.6	1.55
106	do	34-75-52	117.98	490.83	82.0	10.4	1.43
107	do	34-75-42	115.15	479.00	68.7	11.3	1.74
108	do	†34-73-22	112.89	487.60	79.5	17.6	1.26
109	do	*34-76-56	111.14	470.50	71.9	17.5	1.83
110	Dense Unproductive	34-77- 4	110.29	459.83	85.0	9.0	1.72
111	do	34-73- 3	107.77	429.83	82.2	26.2	2.00
112	do	*34-76- 3	97.74	404.17	80.4	18.8	2.01
113	do	34-77-23	89.01	356.00	77.1	14.6	2.09
114	do	34-76- 4	80.90	342.33	81.4	21.3	1.57
115	do	†34-73-40	69.80	308.00	76.2	19.0	1.34
116	do	†34-75-37	63.63	290.60	61.0	15.4	2.67
117	do	*†34-74-40	51.23	245.20	53.7	13.4	2.92

To indicate more fully and definitely the actual variations of the different trees and their relative values to the investigator and the grower, it is necessary to consider the records of actual production of the individual trees. The number of trees included in this study and the mass of data obtained from them make it impracticable to present the complete records of all of the trees in this bulletin; hence, it has been necessary to select a number of trees for this purpose. Tables VIII and X give the detailed performance records of 24 representative lemon trees of the 117 in the investigational plat of the Eureka variety. This list includes examples of all the strains found in the plat and was made by arbitrarily selecting every eighth tree of the Eureka strain as listed in Table VI, every fifth tree of the Shade-Tree strain, every fourth tree of the Small-Open and Dense-Unproductive strains, and both trees of the Dense-Productive and Pear-Shape strains. In each case the highest and lowest ranking trees of each strain are included. This basis was adopted in order to remove all chance of any personal bias in the selection of the trees and is thought to include more representative trees than the basis employed for this purpose in earlier bulletins of this series. Tables VIII and X are thus made to include 10 trees of the Eureka strain, 4 of the Shade-Tree strain, 3 each of the Small-Open and Dense-Unproductive strains, and 2 each of the Dense-Productive and Pear-Shape strains.

TABLE VII.—*Distribution of lemon trees of the Eureka variety in the investigational performance-record plat, showing also the strain and the rank in crop production of each individual tree for the 6-year period from July, 1911, to June, 1917, inclusive.*

[The positions of the trees in ranks 67, 69, 90, 96, 97, 101, 106, 107, 109, 115, 116, and 117 are not here indicated. As shown by their location numbers in Table VI, they were situated at varying distances outside the main body of the plat, and it was thought inadvisable to include them in this table. This orchard is planted on the contour and on that account the trees in rows across it do not bear the same number, counting from the southern end, which is taken as the head of the row. The trees in rows 74 and 75 are numbered one in advance of the nearest one in row 73, and those in rows 76 and 77 are two in advance of those in row 73, as indicated. Explanation of symbols: ⊙=Eureka strain, △=Shade-Tree strain, ⊡=Dense-Productive strain, □=Dense-Unproductive strain, ⊕=Pear-Shape strain, ●=Small-Open strain, ×=not included in the record.]

Serial No. of tree in row.			Number of row.									
			73		74		75		76		77	
Row 73.	Rows 74 and 75.	Rows 76 and 77.	Strain.	Rank.	Strain.	Rank.	Strain.	Rank.	Strain.	Rank.	Strain.	Rank.
......	......	1	......	......	......	......	......	......	×	......	×	......
......	1	2	......	......	×	......	×	......	×	......	×	......
1	2	3	●	51	●	79	⊙	47	□	112	⊙	32
2	3	4	●	86	●	92	⊙	68	□	114	□	110
3	4	5	□	111	△	84	⊙	75	⊙	61	⊙	87
4	5	6	⊙	73	△	98	⊙	58	●	94	⊙	88
5	6	7	⊙	72	⊙	38	●	99	⊙	85	⊙	65
6	7	8	⊙	3	⊙	13	⊙	70	⊙	43	⊙	50
7	8	9	⊙	1	⊙	60	●	81	⊙	83	⊙	76
8	9	10	●	22	⊙	80	⊙	74	⊙	62	⊕	104
9	10	11	⊙	24	⊙	26	⊙	77	⊙	64	⊙	52
10	11	12	⊙	20	⊕	71	⊙	29	⊙	59	⊙	40
11	12	13	⊙	37	□	95	⊙	11	⊙	16	●	78
12	13	14	⊙	25	△	102	△	93	●	89	□	100
13	14	15	⊙	7	⊙	30	△	103	⊙	44	⊙	49
14	15	16	⊙	31	△	63	△	105	⊙	56	⊙	17
15	16	17	△	91	⊙	21	⊙	35	⊙	48	⊙	18
16	17	18	⊡	66	⊙	57	⊙	82	⊙	45	⊙	23
17	18	19	⊙	4	⊙	33	⊙	34	⊙	55	⊙	12
18	19	20	⊙	42	⊙	46	⊙	53	⊙	19	⊙	54
19	20	21	⊡	27	⊙	8	⊙	15	⊙	10	⊙	39
20	21	22	×	......	⊙	2	⊙	14	⊙	36	⊙	28
21	22	23	⊙	6	⊙	5	⊙	41	⊙	9	□	113
22	......	......	△	108	......	......	......	......	......	......	......	......

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive.*

[The weights of annual production are expressed in pounds and ounces, but the fractional averages are stated decimally in pounds.]

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
1. Eureka strain:																										
Green grade—																										
1911–12	301–11	1,100	23– 2	81	16– 9	65	51– 2	192	33– 5	128	24– 5	90	27– 3	99	15–11	61	22–11	81	47– 5	162	12– 8	45	21– 2	71	6–12	25
1912–13	129– 1	517	4–13	17	5– 8	19	3–12	13	39– 6	148	22–15	93	22– 5	91	29– 3	130	1– 3	6	.....	.....	.....	.....	.....	.....	.....	.....
1913–14	45– 5	153	.....	.....	.....	.....	.....	.....	.....	.....	4–11	16	8–13	29	4– 3	14	.....	.....	3–14	12	2– 7	8	10– 6	31	10–15	43
1914–15	411–12	1,482	11– 6	45	5– 9	21	17–12	65	14– 9	56	41–11	160	32–14	124	10– 0	35	77– 2	265	78–14	283	55– 4	196	49– 1	168	17–10	64
1915–16	290–14	1,090	4– 3	16	12–7	47	25–10	98	11– 6	45	18– 5	68	21– 3	80	32– 0	125	48– 2	177	49– 2	183	48– 5	176	16– 3	60	4– 0	15
1916–17	208– 1	820	6– 8	25	7– 5	30	10– 2	39	7– 8	30	19– 8	77	29– 1	125	8– 6	38	.....	.....	52–11	196	27–10	105	39– 6	155	0	0
Average	231.13	860.33	10.00	36.80	9.48	36.40	21.68	81.40	21.23	81.40	21.91	84.00	23.57	91.33	16.57	67.17	37.28	132.25	33.13	119.43	29.23	106.00	27.23	97.00	7.86	29.40
Tree-Ripe grade—																										
1911–12	84– 9	379	0– 8	4	0	0	0	0	0– 5	2	5– 6	28	7– 6	44	6–11	34	19– 6	88	14–11	56	12– 7	50	16– 7	66	1– 6	7
1912–13	47– 5	245	0– 4	1	0–12	4	0– 8	2	4– 9	23	0– 3	1	11– 0	52	28–13	156	1– 4	6	.....	.....	.....	.....	.....	.....	.....	.....
1913–14	2– 0	7	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	1– 6	5	0	0	0–10	2	0	0
1914–15	159–13	676	0	0	0	0	0	0	1– 5	7	1–14	11	17– 2	81	28– 0	130	16– 9	63	45– 2	190	40–13	160	2–10	10	6– 6	24
1915–16	85– 3	408	3–10	16	2– 7	11	4– 9	21	3– 2	15	8–11	36	19– 2	95	6– 0	42	0– 6	3	1– 0	9	8– 1	33	26–11	120	1– 8	7
1916–17	61– 0	278	1– 3	6	0–12	4	0	0	0	0	1– 7	7	9– 7	51	1–11	7	.....	.....	9– 8	39	7– 4	30	29–12	134	0	0
Average	73.31	332.17	1.11	5.40	0.79	3.80	1.01	4.60	1.86	9.40	2.93	13.83	10.68	53.83	11.86	61.50	9.39	40.00	10.24	42.71	13.71	54.60	15.23	66.40	1.85	7.60
Cull grade—																										
1911–12	12– 4	96	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	6–12	56	1–15	12	0–15	6	2– 0	17	0–10	5
1912–13	138– 0	1,308	1– 7	9	1– 8	9	1–10	11	2–13	30	1– 7	12	2– 6	20	30–12	214	96– 1	1,003	.....	.....	.....	.....	.....	.....	.....	.....
1913–14	0– 3	1	.....	.....	.....	.....	.....	.....	.....	.....	0– 3	1	0	0	0	0	.....	.....	0	0	0	0	0	0	0	0
1914–15	16–10	97	0– 2	1	0– 2	1	0	0	0–14	5	1– 6	9	0– 6	2	1– 0	7	0	0	3– 3	18	2– 6	13	4–11	26	2– 8	15
1915–16	21–10	122	1– 4	9	1– 8	9	1– 2	7	0–11	5	1– 2	7	0– 6	3	1– 2	6	0–10	4	0	0	2–15	13	9–15	53	0–15	6
1916–17	14– 2	100	0	0	0	0	0– 7	2	0	0	0– 3	2	0– 1	1	0– 1	1	.....	.....	0– 2	1	2– 0	11	4–10	33	6–10	49
Average	33.80	287.33	0.70	4.75	0.78	4.75	0.80	5.00	1.09	10.00	0.86	6.20	0.64	5.20	6.59	45.60	25.86	265.75	0.75	4.43	1.65	8.60	4.25	25.80	2.14	15.00
Total crop—																										
1911–12	398– 8	1,575	23–10	85	16– 9	65	51– 2	192	33–10	130	29–11	118	34– 9	143	22– 6	95	48–13	225	63–15	230	25–14	101	39– 9	154	8–12	37
1912–13	314– 6	2,070	6– 8	27	7–12	32	5–14	26	46–12	201	24– 9	106	35–11	163	88–12	500	98– 8	1,015	.....	.....	.....	.....	.....	.....	.....	.....
1913–14	47– 8	161	.....	.....	.....	.....	.....	.....	.....	.....	4–14	17	8–13	29	4– 3	14	.....	.....	5– 4	17	2– 7	8	11– 0	33	10–15	43
1914–15	588– 3	2,255	11– 8	46	5–11	22	17–12	65	16–12	68	44–15	180	50– 6	207	39– 0	172	93–11	328	127–3	491	98– 7	369	56– 6	204	26– 8	103

1915-16	397-11	1,620	9- 1	41	16- 6	67	31- 5	126	15- 3	65	28- 2	111	40-11	178	39- 2	173	49- 2	184	50- 2	192	59- 5	222	52-13	233	6- 7	28
1916-17	283- 3	1,198	7-11	31	8- 1	34	10- 9	41	7- 8	30	21- 2	86	38- 9	177	10- 2	46	.....	.....	62- 5	236	30-14	146	73-12	322	6-10	49
Average	338.24	1,479.83	11.68	46.00	10.89	44.00	23.33	90.00	23.96	98.80	25.55	103.00	34.78	149.50	33.93	166.67	72.53	438.00	44.12	166.57	44.59	169.20	46.70	189.20	11.85	52.00
Variable fruits—																										
1914-15	.....	105	.....	2	.....	0	.....	4	.....	3	.....	12	.....	2	.....	5	.....	9	.....	20	.....	17	.....	22	.....	9
1915-16	.....	281	.....	10	.....	0	.....	5	.....	3	.....	24	.....	47	.....	35	.....	59	.....	55	.....	24	.....	18	.....	1
1916-17	.....	192	.....	1	.....	0	.....	0	.....	0	.....	9	.....	32	.....	8	.....	.....	.....	50	.....	38	.....	54	.....	0
Average	.....	192.67	.....	4.33	.....	0	.....	3.00	.....	2.00	.....	15.00	.....	27.00	.....	16.00	.....	22.67	.....	41.67	.....	26.33	.....	31.33	.....	3.33
Average seeds per fruit—																										
1911-12	.....	4.31	.....	9	.....	0	.....	0	.....	2	.....	0	.....	0	.....	4	.....	6	.....	9	.....	7	.....	0	.....	9
1912-13	.....	6.50	.....	6	.....	5	.....	8	.....	4	.....	0	.....	6	.....	11	.....	12	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	5.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	8	.....	4	.....	5	.....	.....	.....	4	.....	2	.....	6	.....	7
1914-15	.....	5.90	.....	3	.....	2	.....	0	.....	0	.....	0	.....	2	.....	6	.....	9	.....	5	.....	14	.....	16	.....	10
1915-16	.....	9.94	.....	7	.....	7	.....	10	.....	9	.....	3	.....	4	.....	4	.....	22	.....	9	.....	15	.....	10	.....	16
Average	.....	6.83	.....	6.40	.....	4.33	.....	6.88	.....	3.73	.....	1.92	.....	3.33	.....	6.42	.....	13.30	.....	7.55	.....	11.33	.....	8.70	.....	11.33
9. Eureka strain:																										
Green grade—																										
1911-12	273- 1	1,007	4-15	18	25- 2	95	38-11	153	44- 4	168	35- 4	126	30-10	112	12- 5	46	8- 0	30	34- 6	118	9-10	35	12- 3	42	17-11	64
1912-13	86- 1	339	2- 4	8	4- 4	16	3-10	13	30- 9	118	18- 6	70	11- 6	47	14- 0	58	1-10	9	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	32- 1	112	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2- 1	8	3- 9	13	.....	.....	4- 6	15	1-15	7	10- 5	35	9-13	34
1914-15	285- 3	1,030	11- 2	41	2-10	10	7-2	28	3- 3	12	2- 0	8	46-11	174	0- 4	1	40-12	147	27- 1	95	62- 3	218	53-14	193	28-5	103
1915-16	221- 3	836	3- 7	14	10- 4	39	14- 3	55	28- 5	109	1- 9	6	0- 9	2	7-13	29	17- 6	66	67- 9	250	44- 4	166	21-13	85	4- 1	15
1916-17	161-10	651	6-10	27	6- 1	29	8-10	34	4- 2	17	6- 9	27	12-11	53	12- 2	51	.....	.....	38-10	148	34-9	135	31-10	130	0	0
Average	176.53	662.50	5.68	21.60	9.67	37.80	14.45	56.60	22.09	84.80	12.75	47.40	17.33	66.00	8.34	33.00	16.94	63.00	24.57	89.42	30.51	112.20	25.96	97.00	11.98	43.20
Tree-Ripe grade—																										
1911-12	88- 0	377	0	0	0	0	0	0	0- 3	1	0- 6	2	4- 4	20	7-13	34	17- 0	83	30- 5	125	7- 2	27	9-11	36	11- 4	49
1912-13	32- 0	161	0-11	3	0- 6	2	0- 5	2	2- 3	11	3- 8	20	10-10	48	12- 6	64	1-15	11	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	2- 5	9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	.....	.....	1- 1	4	0- 7	2	0- 9	2	0- 4	1
1914-15	113-11	456	0	0	0	0	0	0	0	0	0- 2	1	3-10	17	4-14	23	24-13	103	12-14	52	46-15	180	7- 5	28	13- 2	52
1915-16	117- 0	537	8- 4	37	5- 7	26	4- 8	22	3- 5	16	12-10	52	27- 5	132	2- 4	15	0-14	5	1-12	11	13- 8	55	35- 5	157	1-14	9
1916-17	65- 9	302	0	0	0- 6	2	0- 5	2	1-11	8	1-2	6	1-12	10	2- 0	8	.....	.....	7-10	32	6-13	30	41- 4	190	2-10	14
Average	69.76	307.00	1.79	8.00	1.24	6.00	1.03	5.20	1.48	7.20	3.55	16.20	7.93	37.83	4.89	24.00	11.16	50.50	7.66	32.00	14.96	58.80	18.83	82.60	5.83	25.00
Cull grade—																										
1911-12	11- 6	75	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4- 8	35	3-10	21	0- 8	4	0-12	4	2- 0	11
1912-13	129- 4	1,238	0-14	6	0-15	7	0 -2	1	3-11	30	1- 2	13	2- 9	20	2- 2	14	117-13	1,147	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 5	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0- 2	1	.....	.....	0- 3	1	0	0	0	0	0	0
1914-15	14- 3	79	0	0	0	0	0- 6	2	0	0	0- 5	2	0	0	0	0	1-12	13	2- 4	11	2- 4	12	2-12	15	4- 8	24
1915-16	27- 2	172	2- 5	14	0- 5	2	1- 4	8	1- 8	10	0- 6	3	1- 2	11	0- 7	4	2- 1	18	1- 3	8	3- 0	18	8- 6	48	5- 3	28
1916-17	20- 0	167	0-12	1	0	0	0- 2	1	0	0	0- 2	1	0-14	12	0	0	.....	.....	1- 0	7	0-10	5	2-14	20	13-10	120
Average	33.72	288.83	0.98	5.25	0.31	2.25	0.47	3.00	1.30	10.00	0.48	4.75	0.91	8.60	0.53	3.80	31.53	203.25	1.18	6.86	1.27	7.80	2.95	17.40	5.06	36.60

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
9. Eureka strain—Con.																										
Total crop—																										
1911-12	372- 7	1,459	4-15	18	25- 2	95	38-11	153	44- 7	169	35-10	128	34-14	132	20- 2	80	29- 8	148	68- 5	264	17- 4	66	22-10	82	30-15	124
1912-13	247- 5	1,738	3-13	17	5- 9	25	4- 1	16	36- 7	159	23- 0	103	24- 9	115	28- 8	136	121- 6	1,167	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	34-11	123	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2- 1	8	3-11	14	.....	.....	5-10	20	2- 6	9	10-14	37	10- 1	35
1914-15	413- 1	1,565	11- 2	41	2-10	10	7- 8	30	3- 3	12	2- 7	11	50- 5	191	5- 2	24	67- 5	263	42- 3	158	111-6	410	63-15	236	45-15	179
1915-16	365- 5	1,545	14- 0	65	16- 0	67	19-15	85	33- 2	135	14- 9	61	29- 0	145	10- 8	48	20- 5	89	70- 8	269	60-12	239	65- 8	290	11- 2	52
1916-17	247- 3	1,120	7- 6	28	6- 7	31	9- 1	37	5-13	25	7-13	34	15- 5	75	14- 2	59	.....	.....	47- 4	187	42- 0	170	75-12	340	16- 4	134
Average	**280.01**	**1,258.33**	**8.25**	**33.80**	**11.15**	**45.60**	**15.85**	**64.20**	**24.60**	**100.00**	**16.69**	**67.40**	**26.02**	**111.00**	**13.67**	**60.17**	**59.62**	**416.75**	**33.41**	**128.28**	**46.75**	**178.80**	**47.73**	**197.00**	**22.86**	**104.80**
Variable fruits—																										
1914-15	.....	59	.....	5	.....	0	.....	0	.....	2	.....	0	.....	0	.....	0	.....	12	.....	4	.....	4	.....	27	.....	5
1915-16	.....	94	.....	6	.....	0	.....	0	.....	1	.....	1	.....	1	.....	9	.....	16	.....	44	.....	3	.....	12	.....	1
1916-17	.....	102	.....	0	.....	0	.....	0	.....	0	.....	0	.....	8	.....	3	.....	.....	.....	19	.....	35	.....	37	.....	.....
Average	.....	85.00	.....	3.67	.....	0	.....	0	.....	1.00	.....	0.33	.....	3.00	.....	4.00	.....	9.33	.....	22.33	.....	14.00	.....	25.33	.....	2.00
Average seeds per fruit—																										
1911-12	.....	4.52	.....	8	.....	0	.....	0	.....	0	.....	0	.....	3	.....	3	.....	7	.....	12	.....	7	.....	7	.....	7
1912-13	.....	5.33	.....	5	.....	6	.....	8	.....	0	.....	1	.....	5	.....	4	.....	14	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	8.33	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	12	.....	11	.....	.....	.....	6	.....	8	.....	11	.....	7
1914-15	.....	9.07	.....	7	.....	2	.....	4	.....	0	.....	8	.....	5	.....	11	.....	10	.....	9	.....	12	.....	17	.....	10
1915-16	.....	12.94	.....	11	.....	9	.....	10	.....	11	.....	14	.....	8	.....	12	.....	14	.....	16	.....	21	.....	18	.....	11
Average	.....	8.62	.....	7.88	.....	5.75	.....	6.89	.....	3.67	.....	6.27	.....	6.00	.....	7.92	.....	11.64	.....	10.45	.....	12.50	.....	14.20	.....	9.00
17. Eureka strain:																										
Green grade—																										
1911-12	233- 1	837	22- 7	79	10-13	41	22- 5	83	30-14	117	15-10	55	30- 5	109	9-13	36	13-12	48	43-10	156	9- 1	32	19- 0	61	5- 7	20
1912-13	99-12	404	6- 1	21	3- 5	12	2-12	10	26- 1	102	25-10	108	24- 0	99	9- 7	40	2- 8	12	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	8-11	29	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0- 4	1	0	0	.....	.....	0- 4	1	0- 4	1	4- 0	12	3-15	14
1914-15	241- 7	881	8- 7	32	3- 0	12	3-15	15	2- 4	8	4-12	18	47- 2	183	0-10	2	27-12	104	21-13	73	33-14	121	62-14	222	25- 0	91
1915-16	194-12	741	2-14	13	2- 5	9	14-11	57	25- 2	98	3- 5	13	3- 2	14	2-11	10	10- 7	41	47-15	178	51- 8	191	22- 5	85	8- 7	23
1916-17	151-15	605	5- 6	23	4-12	18	6- 7	26	6- 1	25	11-11	48	13- 4	55	12- 8	50	.....	.....	22-10	86	28- 6	110	40-14	164	0	0
Average	154.94	582.83	9.04	33.60	4.84	18.40	10.02	38.20	18.08	70.00	10.17	40.33	19.67	76.83	5.84	23.00	13.61	51.25	19.46	70.57	24.61	91.00	29.81	108.80	8.56	31.46

Tree-Ripe grade—																										
1911-12	87-11	414	1- 2	5	0	0	0	0	1-0	6	0-12	4	8- 2	43	6- 4	33	34- 0	163	22-11	104	0- 2	1	5-10	20	8- 0	35
1912-13	49- 1	256	1-9	6	0-10	3	0- 8	2	2- 9	14	1- 2	6	9-10	47	24- 4	127	8-13	51	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	1- 4	5	.....	.....	.....	.....	.....	.....	.....	.....	0-10	3	0	0	0	0	.....	.....	0-10	2	0	0	0	0	0	0
1914-15	130- 8	550	0	0	0	0	0- 2	1	0	0	0- 3	1	7- 5	36	2- 3	9	50- 9	221	13- 2	56	12- 3	46	19- 4	76	25- 9	104
1915-16	134- 6	628	5-14	27	2- 3	11	2-14	14	7- 6	34	10- 6	42	34- 5	162	2- 5	19	2- 9	18	1-13	10	7- 1	29	46-10	213	11- 0	49
1916-17	55- 5	250	1- 0	6	0- 3	1	0- 6	2	0-15	5	1- 0	6	0-15	5	5- 9	23	.....	.....	12- 8	50	6- 4	27	25- 4	118	1- 5	7
Average	76.36	350.50	1.91	8.80	0.60	3.00	0.78	3.80	2.38	11.80	2.34	10.33	10.05	48.83	6.76	35.17	23.98	113.25	7.25	31.71	5.13	20.60	19.35	85.40	9.18	39.00
Cull grade—																										
1911-12	6- 6	56	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5- 0	46	0-12	5	0- 3	2	0- 7	3	0	0
1912-13	122- 3	1,252	0- 6	2	0-10	5	0	0	0-15	9	2- 4	27	1- 6	11	4-2	38	112- 8	1,160	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0-13	8	.....	.....	.....	.....	.....	.....	.....	.....	0- 7	5	0	0	0	0	.....	.....	0	0	0	0	0- 3	2	0- 3	1
1914-15	14-13	109	0- 2	1	0	0	0-10	4	0- 4	2	0- 4	2	0	0	1- 6	10	2- 8	16	0- 3	2	1- 0	8	4- 2	38	4- 6	26
1915-16	27- 9	176	1-11	12	1-15	13	1- 1	8	1- 0	7	1- 6	7	0- 4	2	0- 5	2	2-15	26	1- 1	9	2- 0	12	6-10	38	7- 5	40
1916-17	14-15	127	0- 4	2	0	0	0	0	0	0	0- 3	2	0- 1	1	0- 4	2	.....	.....	1- 0	9	1- 4	9	3- 2	22	8-13	80
Average	31.11	288.00	0.61	4.25	0.64	4.50	0.42	3.00	0.55	4.50	0.90	8.60	0.34	2.80	1.21	10.40	30.73	312.00	0.43	3.57	0.89	6.20	2.90	20.60	4.14	29.40
Total crop—																										
1911-12	327- 2	1,307	23- 9	84	10-13	41	22- 5	83	31-14	123	16- 6	59	38- 7	152	16- 1	69	52-12	257	67- 1	265	9- 6	35	25- 1	84	13- 7	55
1912-13	271- 0	1,912	8- 0	29	4- 9	20	3- 4	12	29- 9	125	29- 0	141	35- 0	157	37-13	205	123-13	1,223	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	10-12	42	.....	.....	.....	.....	.....	.....	.....	.....	1- 1	8	0- 4	1	0	0	.....	.....	0-14	3	0- 4	1	4- 3	14	4- 2	15
1914-15	386-12	1,540	8- 9	33	3- 0	12	4-11	20	2- 8	10	5- 3	21	54- 7	219	4- 3	21	80-13	341	35- 2	131	47- 1	175	86- 4	336	54-15	221
1915-16	356-11	1,545	10- 7	52	6- 7	33	18-10	79	33- 8	139	15- 1	62	37-11	178	5- 5	31	15-15	85	50-13	197	60- 9	232	75- 9	336	26-12	121
1916-17	222- 3	982	6-10	31	4-15	19	6-13	28	7- 0	30	12-14	56	14- 4	61	18- 5	75	.....	.....	36- 2	145	35-14	146	69- 4	304	10- 2	87
Average	**262.42**	**1,221.33**	**11.44**	**45.80**	**5.95**	**25.00**	**11.14**	**44.40**	**20.89**	**85.40**	**13.26**	**57.83**	**30.01**	**128.00**	**13.61**	**66.83**	**68.33**	**476.50**	**27.14**	**105.85**	**30.63**	**117.80**	**52.06**	**214.80**	**21.87**	**99.80**
Variable fruits—																										
1914-15	.....	33	.....	3	.....	0	.....	.....	.....	1	.....	1	.....	4	.....	0	.....	5	.....	2	.....	6	.....	9	.....	2
1915-16	.....	65	.....	7	.....	2	.....	1	.....	2	.....	1	.....	1	.....	2	.....	5	.....	22	.....	11	.....	9	.....	2
1916-17	.....	93	.....	0	.....	0	.....	0	.....	0	.....	1	.....	5	.....	2	.....	.....	.....	19	.....	30	.....	36	...	0
Average	.....	63.67	.....	3.33	.....	0.67	.....	0.33	.....	1.00	.....	1.00	.....	3.33	.....	1.33	.....	3.33	.....	14.33	.....	15.67	.....	18.00	.....	1.33
Average seeds per fruit—																										
1911-12	.....	4.14	.....	6	.....	0	.....	0	.....	0	.....	0	.....	1	.....	3	.....	2	.....	6	.....	9	.....	14	.....	6
1912-13	.....	5.57	.....	9	.....	10	.....	10	.....	1	.....	0	.....	2	.....	4	.....	10	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	5.10	.....	.....	.....	.....	.....	.....	.....	.....	.....	7	.....	7	.....	0	.....	.....	.....	5	.....	4	.....	4	.....	5
1914-15	.....	7.58	.....	12	.....	12	.....	1	.....	0	.....	4	.....	3	.....	3	.....	6	.....	15	.....	14	.....	12	.....	9
1915-16	.....	12.61	.....	10	.....	12	.....	9	.....	10	.....	16	.....	8	.....	5	.....	22	.....	14	.....	18	.....	13	.....	15
Average	.....	7.86	.....	9.20	.....	9.63	.....	5.67	.....	3.30	.....	5.62	.....	4.09	.....	3.90	.....	10.90	.....	10.60	.....	13.00	.....	10.90	.....	9.30
22. Small-Open strain:																										
Green grade—																										
1911-12	174-14	638	10-13	39	18- 8	70	25-12	96	30- 5	116	16-15	62	16-11	60	9- 0	33	13- 5	46	13-15	47	4-12	17	8- 4	27	6-10	25
1912-13	105-11	422	4-14	17	3-13	14	0-11	2	45-12	173	22-13	95	13- 9	56	13- 9	62	0-10	3	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	59-13	244	.....	.....	.....	.....	.....	.....	.....	.....	2- 5	8	4-15	17	14- 5	49	.....	.....	7- 8	25	4- 3	15	19- 3	60	7- 6	70

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
22. Small-Open strain—Continued.																										
Green grade—Con.																										
1914-15	346-10	1,223	21- 5	82	4-11	19	10-14	41	9- 7	36	57- 8	212	51-10	193	6- 0	22	53- 0	178	42-15	142	52-10	175	28- 0	92	8-10	31
1915-16	279- 1	1,036	7- 2	27	14-15	56	23- 6	89	12-11	48	24- 0	92	19- 2	73	40-10	149	37- 9	136	36- 9	135	38- 6	138	16- 8	63	8- 3	36
1916-17	164-11	625	4-12	18	4- 2	16	5- 6	21	9- 6	36	16- 1	62	18- 2	73	10- 1	37	.....	.....	42- 3	150	20-10	80	33- 0	128	1- 0	4
Average	188.46	698.00	9.78	36.60	9.21	35.00	13.21	49.80	21.51	81.80	23.27	88.50	20.68	78.66	15.59	58.66	26.12	90.75	20.45	71.29	24.11	85.00	20.99	74.00	6.36	32.00
Tree-Ripe grade—																										
1911-12	31- 1	141	0- 3	1	0	0	0	0	0	0	1- 1	7	3- 0	14	4- 9	24	7- 7	35	5-10	22	4- 9	18	3-15	17	0-11	3
1912-13	23- 3	125	0	0	0- 8	2	0	0	2-15	13	0-10	3	1-13	9	17- 5	98	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	1-15	7	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0- 4	1	0- 8	2	.....	.....	0-15	3	0- 4	1	0	0	0	0
1914-15	65- 6	272	0	0	0	0	0	0	0- 7	2	1- 7	7	8- 6	40	5- 7	26	12- 6	49	14-10	61	16-14	64	3- 9	14	2- 4	9
1915-16	62- 4	267	0	0	1-14	10	1- 4	6	2-12	13	2-14	12	18- 2	55	6- 7	41	2-10	15	1- 0	6	3- 7	13	19-10	86	2- 4	10
1916-17	45- 3	203	1- 6	8	0- 6	2	0	0	0- 3	1	0- 4	2	5- 2	26	1- 6	6	.....	.....	5- 5	21	10- 4	41	20- 0	91	0-15	5
Average	38.17	169.17	0.31	1.80	0.55	2.80	0.25	1.20	1.26	5.80	1.04	5.17	6.11	24.17	5.94	32.83	5.61	24.75	3.93	16.14	7.07	27.40	9.43	41.60	1.23	5.40
Cull grade—																										
1911-12	4- 9	42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3- 4	33	1- 5	9	0	0	0	0	0	0
1912-13	63- 5	701	0- 9	4	0-10	6	0- 5	4	1- 7	19	0- 3	3	0- 9	5	23- 2	147	36- 8	513	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	1- 1	10	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	0-10	6	0	0	0- 4	3	0- 3	1
1914-15	10-13	62	0	0	0	0	0- 5	2	0-3	1	1-14	12	0- 4	2	0-10	5	0- 8	3	2- 1	10	2-12	16	1-14	9	0- 6	2
1915-16	12- 2	76	0- 8	4	1-13	12	0- 9	3	0-10	4	2-11	16	0-15	5	0-13	5	0	0	0- 3	1	0- 8	4	2- 5	14	1- 3	8
1916-17	17-10	128	0- 3	1	0	0	0	0	0- 2	2	0- 2	1	1- 0	9	0- 7	4	.....	.....	0- 6	4	0-12	5	1- 9	15	13- 1	87
Average	18.25	169.83	0.31	2.25	0.61	4.50	0.30	2.25	0.59	6.50	0.97	6.40	0.55	4.20	5.00	32.20	10.06	137.25	0.65	4.29	0.80	5.00	1.20	8.20	2.96	19.60
Total crop—																										
1911-12	210- 8	821	11- 0	40	18- 8	70	25-12	96	30- 5	116	18- 0	69	19-11	74	13- 9	57	24- 0	114	20-14	78	9- 5	35	12- 3	44	7- 5	28
1912-13	192- 3	1,248	5- 7	21	4-15	22	1- 0	6	50- 2	205	23-10	101	15-15	70	54- 0	307	37- 2	516	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	62-13	261	.....	.....	.....	.....	.....	.....	.....	.....	2- 5	8	5- 3	18	14-13	51	.....	.....	9- 1	34	4- 7	16	19- 7	63	7- 9	71
1914-15	422-13	1,557	21- 5	82	4-11	19	11- 3	43	10- 1	39	60-13	231	60- 4	235	12- 1	53	65-14	230	59-10	213	72- 4	255	33- 7	115	11- 4	42
1915-16	353- 7	1,379	7-10	31	18-10	78	25- 3	98	16- 1	65	29- 9	120	38- 3	133	47-14	195	40- 3	151	37-12	142	42- 5	155	38- 7	163	11-10	48
1916-17	227- 8	956	6- 5	27	4- 8	18	5- 6	21	9-11	39	16- 7	65	24- 4	108	11-14	47	.....	.....	47-14	175	31-10	126	54- 9	234	15- 0	96
Average	**244.88**	**1,037.00**	**10.34**	**40.20**	**10.25**	**41.40**	**13.70**	**52.80**	**23.25**	**92.80**	**25.13**	**99.00**	**27.25**	**106.33**	**25.69**	**118.33**	**41.80**	**252.75**	**25.02**	**91.71**	**31.98**	**117.40**	**31.61**	**123.80**	**10.55**	**57.00**

Variable fruits—																									
1914-15	.....	181	.....	9	.....	4	.....	3	.....	5	.....	31	.....	18	.....	3	.....	16	.....	17	.....	34	.....	33	.....	8
1915-16	.....	400	.....	15	.....	6	.....	7	.....	13	.....	28	.....	37	.....	73	.....	81	.....	60	.....	31	.....	45	.....	4
1916-17	.....	217	.....	1	.....	0	.....	0	.....	9	.....	13	.....	19	.....	8	.....	.....	.....	57	.....	48	.....	62	.....	0
Average	.....	266.00	.....	8.33	.....	3.33	.....	3.33	.....	9.00	.....	24.00	.....	24.67	.....	28.00	.....	32.33	.....	44.67	.....	37.67	.....	46.67	.....	4.00
Average seeds per fruit—																									
1911-12	.....	2.71	.....	4	.....	0	.....	0	.....	0	.....	0	.....	0	.....	1	.....	3	.....	7	.....	4	.....	9	.....	2
1912-13	.....	2.05	.....	2	.....	7	.....	0	.....	3	.....	0	.....	0	.....	0	.....	2	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	6.36	.....	.....	.....	.....	.....	.....	.....	.....	.....	5	.....	3	.....	4	.....	.....	.....	4	.....	5	.....	12	.....	13
1914-15	.....	4.48	.....	4	.....	12	.....	3	.....	0	.....	1	.....	0	.....	1	.....	0	.....	6	.....	16	.....	9	.....	6
1915-16	.....	5.15	.....	7	.....	8	.....	4	.....	3	.....	2	.....	3	.....	0	.....	0	.....	7	.....	13	.....	7	.....	6
Average	.....	4.16	.....	4.71	.....	6.88	.....	2.38	.....	2.00	.....	1.25	.....	1.08	.....	0.85	.....	1.22	.....	5.90	.....	10.60	.....	8.90	.....	6.50
26. Eureka strain:																									
Green grade—																									
1911-12	260- 6	946	14-10	55	7- 6	30	28- 5	103	46-11	170	14-14	56	30-15	111	7- 4	27	25- 1	90	34- 0	123	23- 6	84	19- 4	66	8-10	31
1912-13	108- 4	432	4- 8	16	4- 3	16	1- 9	6	34-12	130	7- 9	30	14- 0	54	37- 1	161	4-10	19	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	45-15	156	.....	.....	.....	.....	.....	.....	.....	.....	0- 4	1	8- 9	29	10- 0	34	.....	.....	7- 5	23	2-14	10	11- 2	36	5-13	23
1914-15	269- 9	932	18-10	33	1- 5	5	2-13	11	1-11	6	9-10	36	27-13	104	2-12	11	34- 1	120	47- 6	168	60- 1	214	45-12	159	17-11	65
1915-16	169- 8	652	3-12	15	14- 5	54	20-14	80	15- 1	60	4- 5	17	6-15	27	8- 7	33	24- 1	90	34-13	135	22- 7	84	10- 4	41	4- 4	16
1916-17	91-12	365	1-12	7	1- 8	6	2- 3	9	4- 7	18	10- 4	43	18- 2	77	6- 4	25	.....	.....	20- 4	75	13- 0	50	14- 0	55	0	0
Average	157.56	580.50	8.65	25.20	5.73	22.20	11.15	41.80	20.53	76.80	7.81	30.50	17.73	67.00	11.96	48.50	21.95	79.75	20.53	74.86	24.35	88.40	20.08	71.40	7.28	27.00
Tree-Ripe grade—																									
1911-12	93-13	427	3- 4	15	0	0	0- 2	1	0- 9	3	2- 8	12	9- 4	42	3- 6	18	32-15	158	20- 5	82	7- 9	31	9- 6	42	4- 9	23
1912-13	15-12	82	0-10	3	1- 2	6	0- 8	3	2- 4	12	0- 6	2	0- 8	3	8-12	44	1-10	9	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	3- 5	13	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0- 9	2	.....	.....	1-14	7	0- 6	2	0- 8	2	0	0
1914-15	83-10	351	0	0	0	0	0	0	0- 3	1	0-13	4	5- 2	26	5- 6	26	19-13	81	21- 4	88	14- 6	59	8- 3	31	8- 8	35
1915-16	83- 4	399	2-11	13	5- 0	23	2-14	15	3-11	18	7- 9	30	15- 4	83	6- 7	38	0-13	4	0- 5	3	5-12	23	31- 0	141	1-14	8
1916-17	53- 9	246	0-11	4	0- 8	3	0- 2	1	1- 8	7	0-12	4	7-11	41	1- 0	4	.....	.....	10-10	42	5- 9	25	25- 2	115	0	0
Average	55.55	253.00	1.45	7.00	1.33	6.40	0.73	4.00	1.64	8.20	2.00	8.67	6.30	32.50	4.25	22.00	13.80	63.00	7.77	31.71	6.73	28.00	14.84	66.20	2.99	13.20
Cull grade—																									
1911-12	22- 1	169	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	15- 8	124	1- 4	9	1- 4	9	2- 8	18	1- 9	9
1912-13	111-11	989	2- 8	16	0- 6	2	0- 9	4	1- 4	7	0- 3	2	0- 4	3	11- 7	71	95- 2	884	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 9	4	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0- 4	0	0	0	.....	.....	0- 6	3	0	0	0	0	0- 3	1
1914-15	9- 0	51	0- 7	4	0	0	0	0	0- 4	2	0	0	0-12	4	0- 4	1	1- 9	8	1-10	8	1- 5	8	1-11	10	1- 2	6
1915-16	21-14	136	0- 8	4	1- 8	11	1- 9	9	0- 9	4	0- 9	4	0- 7	2	0-12	4	0-15	7	0- 5	2	2- 8	15	10- 1	62	2- 3	12
1916-17	7- 7	56	0- 4	2	0	0	0	0	0	0	0- 2	2	0-12	6	0	0	.....	.....	0- 5	2	0- 4	2	2- 4	16	3- 8	26
Average	28.77	234.17	0.92	6.50	0.47	3.25	0.53	0.20	0.52	3.25	0.18	1.60	0.44	3.00	2.49	15.20	28.28	255.75	0.55	3.43	1.06	6.80	3.30	21.20	1.71	10.80
Total crop—																									
1911-12	376-4	1,542	17-14	70	7- 6	30	28- 7	104	47- 4	173	17- 6	68	40- 3	153	10-10	45	73- 8	372	55- 9	214	32- 3	124	31- 2	126	14-12	63
1912-13	235-11	1,503	7-10	35	5-11	24	2-10	13	38- 4	149	8- 2	34	14-12	60	57- 4	276	101-6	912	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	49-13	173	.....	.....	.....	.....	.....	.....	.....	.....	0- 4	1	8- 9	29	10- 9	36	.....	.....	9- 9	33	3- 4	12	11-10	38	6- 0	24
1914-15	362- 3	1,334	19- 1	37	1- 5	5	2-13	11	2- 2	9	10- 7	40	33-11	134	8- 6	38	55- 7	209	70- 4	264	75-12	281	55-10	200	27- 5	106

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
26. Eureka strain—Con.																										
Total crop—Con.																										
1915-16	274-10	1,187	6-15	32	20-13	88	25- 5	104	19- 5	82	12- 7	51	22-10	112	15-10	75	25-13	101	35- 7	140	30-11	122	51- 5	244	8- 5	36
1916-17	152-12	667	2-11	13	2- 0	9	2- 5	10	5-15	25	11- 2	49	26- 9	124	7- 4	29	.....	.....	31- 3	119	18-13	77	41- 6	186	3- 8	26
Average	**241. 89**	**1, 067. 67**	**10. 83**	**37. 40**	**7. 43**	**31. 20**	**12. 30**	**48. 40**	**22. 58**	**87. 60**	**9. 96**	**40. 50**	**24. 40**	**102. 00**	**18. 28**	**83. 17**	**64. 03**	**398. 50**	**28. 85**	**110. 00**	**32. 14**	**123. 20**	**38. 21**	**158. 80**	**11. 98**	**51. 00**
Variable fruits—																										
1914-15	.....	74	.....	1	.....	1	.....	0	.....	0	.....	0	.....	4	.....	1	.....	12	.....	16	.....	11	.....	21	.....	7
1915-16	.....	102	.....	6	.....	4	.....	5	.....	2	.....	5	.....	4	.....	3	.....	22	.....	37	.....	4	.....	10	.....	0
1916-17	.....	107	.....	0	.....	0	.....	0	.....	0	.....	4	.....	13	.....	2	.....	.....	.....	38	.....	27	.....	23	.....	0
Average	.....	94. 33	.....	2. 33	.....	1. 67	.....	1. 67	.....	0. 67	.....	3. 00	.....	7. 00	.....	2. 00	.....	11. 33	.....	30. 33	.....	14. 00	.....	18. 00	.....	2. 33
Average seeds per fruit—																										
1911-12	.....	5. 09	.....	4	.....	1	.....	4	.....	0	.....	0	.....	0	.....	0	.....	12	.....	7	.....	9	.....	5	.....	15
1912-13	.....	6. 33	.....	10	.....	5	.....	7	.....	7	.....	3	.....	6	.....	3	.....	9	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	7. 31	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....	4	.....	10	.....	.....	.....	5	.....	11	.....	7	.....	5
1914-15	.....	8. 03	.....	4	.....	5	.....	0	.....	4	.....	8	.....	3	.....	4	.....	5	.....	10	.....	18	.....	13	.....	12
1915-16	.....	9. 92	.....	9	.....	12	.....	8	.....	6	.....	4	.....	8	.....	4	.....	14	.....	24	.....	13	.....	5	.....	10
Average	.....	7. 63	.....	7. 40	.....	7. 00	.....	5. 89	.....	4. 73	.....	4. 45	.....	4. 83	.....	4. 31	.....	9. 91	.....	12. 00	.....	13. 60	.....	8. 20	.....	10. 50
27. Dense-Productive strain:																										
Green grade—																										
1911-12	147- 8	531	9- 3	33	13- 5	52	24-12	90	30- 4	109	11- 2	40	20- 8	73	7-13	29	5-12	22	13- 3	43	3-13	13	5-14	19	1-15	8
1912-13	82- 0	326	2- 3	8	0-14	3	1- 4	5	19- 2	73	22-14	88	20- 6	80	15- 5	69	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	30-15	107	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1- 9	5	2- 5	8	.....	.....	5- 0	16	1- 7	5	11- 1	36	9- 9	30
1914-15	337- 1	1,194	19- 5	76	2- 0	8	10-14	42	6- 3	23	25- 8	96	31- 4	116	3- 3	12	45- 5	153	57- 3	198	81-10	283	40-11	138	13-15	49
1915-16	267-14	1,011	2-14	11	10- 9	39	34- 3	131	21-8	84	6-14	26	15-13	60	20- 5	78	30- 8	114	43-12	164	44- 3	162	24-11	95	12-10	47
1916-17	170- 1	654	4-10	18	3- 5	13	3- 8	14	9- 1	36	12- 3	48	18- 9	77	15- 8	58	.....	.....	49- 4	177	19-13	76	33-12	135	0- 8	2
Average	172. 57	637. 17	7. 64	29. 20	6. 01	23. 00	14. 91	56. 40	17. 23	65. 00	15. 71	59. 60	18. 01	68. 50	10. 74	42. 33	20. 39	72. 25	24. 05	85. 42	30. 18	107. 80	23. 21	84. 60	7. 71	28. 60
Tree-Ripe grade—																										
1911-12	18- 0	82	2- 4	9	0	0	0	0	0	0	0-10	4	2-11	15	1- 8	8	2- 2	11	3- 0	12	2-11	11	2- 3	9	0-15	3
1912-13	25- 2	128	0- 4	1	0- 8	3	0- 7	3	2- 6	12	2- 4	10	2- 9	12	16-12	87	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	1- 2	5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	.....	.....	0-12	3	0- 6	2	0	0	0	0

1914-15	85- 7	353	0	0	0	0	0	0	0- 3	1	0- 9	3	5- 8	28	2-14	15	23- 5	93	19- 1	79	21-14	88	5- 4	20	6-13	26
1915-16	116- 6	547	1-13	8	2- 0	9	2-14	14	2- 8	12	22- 1	86	38- 0	186	5-12	39	1-10	13	1- 4	8	4- 1	17	30- 9	137	3-14	18
1916-17	44-11	206	0-12	4	0- 5	2	0	0	0	0	1- 2	6	5- 7	30	1- 0	5	.....	......	8- 9	33	8- 6	35	18- 6	87	0-12	4
Average	48.46	220.17	1.01	4.40	0.56	2.80	0.66	3.40	1.01	5.00	5.33	21.80	9.03	45.17	4.65	25.67	6.77	29.25	4.66	19.28	7.48	30.60	11.28	50.60	2.48	10.20
Cull grade—																										
1911-12	7- 5	56	.....	......	.....	.....	.....	.....	.....	......	.....	......	.....	......	.....	......	5- 7	44	0- 5	2	0-13	5	0- 3	2	0- 9	3
1912-13	62-12	841	0-10	4	0- 5	2	0-14	6	0-14	8	0-14	8	2- 2	17	18- 9	122	38- 8	674	.....	......	.....	......	.....	......	.....	.....
1913-14	0-11	4	.....	......	.....	.....	.....	.....	.....	......	.....	......	0	0	0	0	.....	......	0	0	0- 6	2	0- 3	1	0- 2	1
1914-15	9-14	54	0- 2	1	0	0	0	0	0	0	0- 5	2	0	0	0- 7	3	1-14	10	1-10	8	1- 3	7	2-14	15	1- 7	8
1915-16	23-11	146	0- 4	3	1-10	12	0- 9	4	0- 4	2	1-10	10	0-14	5	1-14	14	0	0	0-11	4	2- 4	13	6-15	42	6-12	37
1916-17	17-13	139	0-10	5	0- 4	2	0	0	0	0	0- 8	5	1- 5	11	0- 2	1	.....	......	1- 8	12	2- 0	15	2- 7	20	9- 1	68
Average	20.35	206.67	0.41	3.25	0.55	4.00	0.36	2.50	0.28	2.50	0.83	6.25	0.86	6.60	4.20	28.00	11.45	182.00	0.59	3.71	1.33	8.40	2.53	16.00	3.59	23.40
Total crop—																										
1911-12	172-13	669	11- 7	42	13- 5	52	24-12	90	30- 4	109	11-12	44	23- 3	88	9- 5	37	13- 5	77	16- 8	57	7- 5	29	8- 4	30	3- 7	14
1912-13	169-14	1,295	3- 1	13	1-11	8	2- 9	14	22- 6	93	26- 0	106	25- 1	109	50-10	278	38- 8	674	.....	......	.....	......	.....	......	.....	.....
1913-14	32-12	116	.....	......	.....	.....	.....	.....	.....	......	.....	......	1- 9	5	2- 5	8	.....	......	5-12	19	2- 3	9	11- 4	37	9-11	38
1914-15	432- 6	1,601	19- 7	77	2- 0	8	10-14	42	6- 6	24	26- 6	101	36-12	144	6- 8	30	70- 8	256	77-14	285	104-11	378	48-13	173	22- 3	83
1915-16	407-15	1,704	4-15	22	14- 3	60	37-10	149	24- 4	98	30- 9	122	54-11	251	27-15	131	32- 2	127	45-11	176	50- 8	192	62-3	274	23- 4	102
1916-17	232- 9	999	6- 0	27	3-14	17	3- 8	14	9- 1	36	13-13	59	25- 5	118	16-10	64	.....	......	59- 5	222	30- 3	126	54- 9	242	10- 5	74
Average	**241.39**	**1,064.00**	**8.98**	**36.20**	**7.01**	**29.00**	**15.86**	**61.80**	**18.46**	**72.00**	**21.70**	**86.40**	**27.76**	**119.17**	**18.89**	**91.34**	**38.61**	**283.50**	**29.30**	**108.42**	**38.97**	**146.80**	**37.01**	**151.20**	**13.77**	**62.20**
Variable fruits—																										
1914-15	......	128	.....	10	.....	2	.....	1	.....	0	.....	2	.....	8	.....	2	.....	19	.....	29	......	24	.....	20	.....	11
1915-16	......	243	.....	10	.....	2	.....	10	.....	3	.....	9	.....	30	.....	36	.....	48	.....	51	......	13	.....	24	.....	7
1916-17	......	201	.....	0	.....	0	.....	0	.....	2	.....	8	.....	18	.....	18	.....	......	.....	58	......	43	.....	54	.....	0
Average	......	190.67	.....	6.67	.....	1.33	.....	3.67	.....	1.67	.....	6.33	.....	18.67	.....	18.67	.....	22.33	.....	46.00	......	26.67	.....	32.67	.....	6.00
Average seeds per fruit—																										
1911-12	......	2.86	.....	5	.....	1	.....	0	.....	0	.....	0	.....	0	.....	0	.....	1	.....	7	......	7	.....	7	.....	3
1912-13	......	3.05	.....	7	.....	2	.....	9	.....	2	.....	0	.....	0	.....	0	.....	7	.....	......	......	......	.....	......	.....	.....
1913-14	......	7.00	.....	.....	.....	.....	.....	.....	.....	......	.....	......	.....	3	.....	11	.....	......	.....	4	......	8	.....	11	.....	5
1914-15	......	6.41	.....	4	.....	10	.....	0	.....	1	.....	2	.....	0	.....	2	.....	3	.....	10	......	14	.....	17	.....	8
1915-16	......	8.97	.....	7	.....	10	.....	9	.....	5	.....	2	.....	7	.....	4	.....	11	.....	13	......	12	.....	14	.....	13
Average	......	5.97	.....	5.80	.....	6.13	.....	6.75	.....	2.44	.....	1.09	.....	2.03	.....	2.42	.....	4.88	.....	9.30	......	10.45	.....	13.00	.....	8.00
35. Eureka strain: Green grade—																										
1911-12	211- 3	776	24-15	95	11- 1	44	26- 6	100	51- 9	186	37-13	138	17-14	64	6-13	26	5- 0	18	12- 9	43	3- 9	13	10- 0	35	3-10	14
1912-13	81- 4	317	1-15	7	4- 0	15	2-11	10	31- 9	118	19-15	81	14- 7	58	6- 4	26	0- 7	2	.....	......	......	......	.....	......	.....	.....
1913-14	50-13	177	.....	.....	.....	.....	.....	.....	.....	......	0	0	1- 6	5	8- 9	29	.....	......	3- 7	12	1- 3	4	22-14	75	13- 6	52
1914-15	227- 5	830	13-11	52	4-13	18	14- 5	52	5- 4	21	14-15	58	47- 0	181	1- 5	4	20- 6	72	19- 7	69	25- 4	88	39- 6	136	21- 9	79
1915-16	198- 7	755	2- 7	10	10-10	39	16-13	65	32-11	129	4-14	19	3-11	14	15- 2	55	19-11	73	13-14	52	39- 9	145	30-10	121	8- 7	33
1916-17	158- 2	616	3- 7	15	3- 1	12	1- 1	4	7-10	30	11- 3	44	21-14	93	3-12	14	.....	......	28-14	102	38-11	148	37-10	150	0-15	4
Average	154.52	578.50	9.29	35.80	6.71	25.60	12.25	46.20	25.74	96.80	14.79	56.67	17.71	69.17	6.97	25.67	11.37	41.25	11.17	39.71	21.65	79.60	28.10	103.40	9.59	36.40

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
35. Eureka strain—Con.																										
Tree-Ripe grade—																										
1911-12	50-13	228	0- 6	2	0	0	0	0	1- 1	6	2-12	13	9- 2	41	5-11	28	14-10	71	8-15	33	1-11	7	4- 5	17	2- 4	10
1912-13	21- 2	108	0-10	3	1- 0	5	0- 3	1	2- 7	13	3- 0	16	2- 8	11	10- 8	55	0-14	4	......	......	......	......	......	......	......	......
1913-14	5- 1	19	......	......	......	......	......	......	......	......	0	0	0	0	1- 6	5	......	......	1- 7	5	0- 3	1	1- 5	5	0-12	3
1914-15	72-12	340	0- 4	1	0	0	0- 3	1	0	0	0-13	4	33- 0	178	0	0	10- 5	44	7-10	32	7- 6	28	7- 3	28	6- 0	24
1915-16	116- 5	556	3- 0	14	4-12	22	4-15	24	4- 5	21	14-10	60	33-11	167	3-12	28	1- 6	9	0	0	3- 1	13	33- 4	154	9- 9	44
1916-17	56- 7	358	1-12	9	0	0	0- 3	1	1- 2	5	0- 6	2	7- 8	41	0-15	4	......	......	11- 1	43	5-11	24	26- 3	220	1-10	9
Average	53.75	268.17	1.20	5.80	1.15	5.40	1.10	5.40	1.79	9.00	3.59	15.83	14.30	73.00	3.71	20.00	6.79	32.00	4.15	16.14	3.60	14.60	14.45	84.80	4.04	18.00
Cull grade—																										
1911-12	10- 1	78	......	......	......	......	......	......	......	......	......	......	......	......	......	......	8- 2	65	0-14	4	0- 2	3	0- 4		0-11	4
1912-13	89-13	815	0- 4	2	0- 7	4	0- 4	2	0-12	9	0- 6	4	11- 5	10	16- 6	109	60- 1	675	......	......	......	......	......	......	......	......
1913-14	1-12	11	......	......	......	......	......	......	......	......	0- 6	3	0	0	0- 2	1	......	......	0- 4	2	0	0	0- 6	2	0-10	3
1914-15	11-10	70	0- 4	2	0- 3	1	0- 7	2	0	0	0- 3	1	0	0	0- 4	2	2- 7	15	0	0	0-14	6	3-10	23	3- 6	18
1915-16	25-10	160	0- 4	2	1- 5	9	1 -0	8	1-10	13	1- 4	8	0- 2	1	0- 7	2	0- 7	3	0-15	5	1- 2	7	6-10	41	10- 8	61
1916-17	14- 5	116	0-15	7	0	0	0- 2	1	0- 3	2	0	0	0-14	10	0	0	......	......	0-10	5	1- 0	7	2- 2	17	8- 7	67
Average	25.53	208.33	0.42	3.25	0.48	3.50	0.45	3.25	0.64	6.00	0.44	3.20	2.46	4.20	3.44	22.80	17.77	189.50	0.38	2.28	0.63	4.60	2.60	17.00	4.72	30.60
Total crop—																										
1911-12	272- 1	1,082	25- 5	97	11- 1	44	26- 6	100	52-10	192	40- 9	151	27- 0	105	12- 8	54	27-12	154	22- 6	80	5- 6	23	14- 9	54	6- 9	28
1912-13	192- 3	1,240	2-13	12	5- 7	24	3- 2	13	34-12	140	23- 5	101	28- 4	79	33- 2	190	61- 6	681	......	......	......	......	......	......	......	......
1913-14	57-10	207	......	......	......	......	......	......	......	......	0- 6	3	1- 6	5	10- 1	35	......	......	5- 2	19	1- 6	5	24- 9	82	14-12	58
1914-15	311-11	1,240	14- 3	55	5- 0	19	14-15	55	5- 4	21	15-15	63	80- 0	359	1- 9	6	33- 2	131	27- 1	101	33- 8	122	50- 3	187	30-15	121
1915-16	340- 6	1,471	5-11	26	16-11	70	22-12	97	38-10	163	20-12	87	37- 8	182	19- 5	85	21- 8	85	14-13	57	43-12	165	70- 8	316	28- 8	138
1916-17	228-14	1,090	6- 2	31	3- 1	12	1- 6	6	8-15	37	11- 9	46	30- 4	144	4-11	18	......	......	40- 9	150	45- 6	179	65-15	387	11- 0	80
Average	**233.80**	**1,055.00**	**10.83**	**44.20**	**8.25**	**33.80**	**13.71**	**54.20**	**28.04**	**110.60**	**18.75**	**75.17**	**34.06**	**145.67**	**13.54**	**64.67**	**35.93**	**262.75**	**15.70**	**58.14**	**25.88**	**98.80**	**45.15**	**205.20**	**18.35**	**85.00**
Variable fruits—																										
1914-15	......	76	......	3	......	0	......	2	......	1	......	0	......	5	......	0	......	6	......	8	......	5	......	32	......	14
1915-16	......	163	......	3	......	0	......	6	......	7	......	4	......	8	......	31	......	36	......	18	......	16	......	30	......	4
1916-17	......	122	......	0	......	0	......	0	......	2	......	4	......	11	......	4	......	......	......	19	......	49	......	33	......	0
Average	......	120.33	......	2.00	...	0	......	2.67	......	3.33	......	2.67	......	8.00	......	11.67	......	14.00	......	15.00	......	23.33	......	31.67	......	6.00

Average seeds per fruit—																										
1911-12	.....	2.23	.....	0	.....	0	.....	0	.....	3	.....	0	.....	0	.....	1	.....	1	.....	7	.....	0	.....	5	.....	7
1912-13	.....	2.96	.....	6	.....	7	.....	2	.....	0	.....	2	.....	0	.....	2	.....	3	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	4.31	.....	.....	.....	.....	.....	.....	.....	.....	.....	3	.....	8	.....	2	.....	.....	.....	3	.....	1	.....	8	.....	5
1914-15	.....	4.37	.....	5	.....	2	.....	1	.....	0	.....	4	.....	0	.....	2	.....	1	.....	13	.....	7	.....	4	.....	8
1915-16	.....	6.71	.....	8	.....	7	.....	3	.....	6	.....	4	.....	2	.....	3	.....	3	.....	14	.....	11	.....	11	.....	9
Average	.....	4.37	.....	5.36	.....	5.33	.....	2.00	.....	2.67	.....	3.00	.....	1.55	.....	2.15	.....	2.45	.....	8.89	.....	5.60	.....	7.09	.....	7.45
43. Eureka strain:																										
Green grade—																										
1911-12	241- 5	892	13- 4	50	6-15	28	25-11	100	45- 2	167	29-10	107	27- 6	99	12- 0	46	13- 5	52	29-15	104	11- 2	41	22- 5	79	4-10	19
1912-13	84- 1	341	0-13	3	3- 0	11	1- 7	6	25-13	101	21- 9	90	16-15	68	14- 8	62	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	5- 9	20	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0- 4	1	0	0	.....	.....	0-10	2	0- 9	2	2-10	9	1- 8	6
1914-15	222-11	806	3- 8	12	0- 7	2	4-11	16	4- 0	16	10-12	42	30- 0	115	0-15	3	18-10	67	22- 3	78	55- 4	195	57- 1	203	15- 4	57
1915-16	171- 3	648	3- 5	14	4- 2	16	7- 8	29	9- 9	38	2-14	10	0-12	3	4- 4	17	15- 7	62	53- 3	195	30- 0	108	35- 0	136	5- 3	20
1916-17	109- 2	432	5-10	22	5-12	23	3- 6	13	7- 2	29	9- 2	37	21- 7	88	6- 3	25	.....	.....	17- 0	65	17- 2	65	16- 6	65	0	0
Average	138.99	523.17	5.30	20.20	4.05	16.00	8.54	32.80	18.33	70.20	12.32	47.67	16.14	62.33	6.31	25.50	11.84	45.25	17.56	63.43	22.81	82.20	26.68	98.40	5.31	20.40
Tree-Ripe grade—																										
1911-12	116- 1	529	1-14	9	0	0	0	0	0 -5	2	0- 5	2	10- 9	51	6- 9	31	35-11	180	25- 9	100	12-11	54	12-10	52	9-14	48
1912-13	24-11	131	2- 3	10	1- 4	6	0- 7	3	2- 2	15	1-12	10	4- 0	20	12- 3	63	0-12	4	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 4	1	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	0	0	0	0	0	0	0- 4	1
1914-15	91- 2	369	0- 4	1	0	0	0	0	0	0	0- 3	1	2- 0	10	2-14	12	26-12	106	14-10	61	32-10	131	3-13	16	8- 0	31
1915-16	58- 9	276	4-12	20	2-11	13	1- 0	5	3- 3	15	7- 2	28	8-12	44	2-10	18	3-14	21	0- 2	1	3-13	15	18- 2	85	2- 8	11
1916-17	43- 6	188	1- 4	7	0-11	4	0	0	1- 9	7	0-14	5	2-13	14	3-13	16	.....	.....	5- 4	21	4-13	16	21-12	95	0- 9	3
Average	55.68	249.00	2.06	9.40	0.93	4.60	0.29	1.60	1.44	7.80	1.71	7.67	4.69	23.17	4.68	23.33	16.76	77.75	6.51	26.14	10.79	43.20	11.26	49.60	4.24	18.80
Cull grade—																										
1911-12	17- 2	119	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9- 6	69	3-10	23	1- 2	7	1- 2	7	1-14	13
1912-13	120- 8	1,233	1- 0	9	0-10	5	0- 7	4	0-12	9	1-15	28	1-11	15	3- 2	24	110-15	1,139	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 3	1	.....	.....	.....	.....	.....	.....	.....	.....	0- 3	1	0	0	0	0	.....	.....	0	0	0	0	0	0	0	0
1914-15	10-15	60	0- 2	2	0	0	0	0	0	0	0	0	0	0	0- 8	4	1- 1	5	2- 0	10	0-12	5	6- 3	32	0- 5	2
1915-16	16-10	100	0-15	6	0- 9	4	0- 4	2	0- 6	3	0-10	5	0- 4	2	0	0	0	0	0- 6	4	1- 8	7	7- 7	42	4- 5	25
1916-17	9-15	72	0- 1	1	0	0	0	0	0- 4	2	0- 5	3	0- 1	1	0- 3	1	.....	.....	0- 3	2	1- 3	8	1- 2	8	6- 9	46
Average	29.22	264.17	0.53	4.50	0.30	2.25	0.17	1.50	0.34	3.50	0.61	7.40	0.40	3.60	0.76	5.80	30.35	303.25	0.88	5.57	0.91	5.40	3.18	17.80	2.61	17.20
Total crop—																										
1911-12	374- 8	1,540	15- 2	59	6-15	28	25-11	100	45- 7	169	29-15	109	37-15	150	18- 9	77	58- 6	301	59- 2	227	24-15	102	36- 1	138	16- 6	80
1912-13	229- 4	1,705	4- 0	22	4-14	22	2- 5	13	28-11	125	25-4	128	22-10	103	29-13	149	111-11	1,143	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	6- 0	22	.....	.....	.....	.....	.....	.....	.....	.....	0- 3	1	0- 4	1	0	0	.....	.....	0-10	2	0- 9	2	2-10	9	1-12	7
1914-15	324-12	1,235	3-14	15	0- 7	2	4-11	16	4- 0	16	10-15	43	32- 0	125	4- 5	19	46- 7	178	38-13	149	88-10	331	67- 1	251	23- 9	90
1915-16	246- 6	1,024	9- 0	40	7- 6	33	8-12	36	13- 2	56	10-10	43	9-12	49	6-14	35	19- 5	83	53-11	200	35- 5	130	60- 9	263	12- 0	56
1916-17	162- 7	692	6-15	30	6- 7	27	3- 6	13	8-15	38	10- 5	45	24- 5	103	10- 3	42	.....	.....	22- 7	88	23- 2	89	39- 4	168	7- 2	49
Average	223.89	1,036.33	7.79	33.20	5.21	22.40	8.96	35.60	20.04	80.80	14.54	61.50	21.15	88.50	11.63	53.66	58.95	426.25	24.95	95.14	34.51	130.80	41.11	165.80	12.16	56.40

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
43. Eureka strain—Con. Variable fruits—																										
1914–15	.....	40	.....	1	.....	0	.....	0	.....	1	.....	0	.....	1	.....	1	.....	6	.....	3	.....	11	.....	13	.....	3
1915–16	.....	84	.....	9	.....	0	.....	1	.....	1	.....	2	.....	2	.....	5	.....	11	.....	28	.....	6	.....	19	.....	0
1916–17	.....	74	.....	0	.....	2	.....	0	.....	0	.....	2	.....	8	.....	6	.....	.....	.....	11	.....	22	.....	23	.....	0
Average	.....	66.00	.....	3.33	.....	0.67	.....	0.33	.....	0.67	.....	1.33	.....	3.67	.....	4.00	.....	5.67	.....	14.00	.....	13.00	.....	18.33	.....	1.00
Average seeds per fruit—																										
1911–12	.....	4.09	.....	6	.....	6	.....	0	.....	0	.....	5	.....	0	.....	3	.....	4	.....	4	.....	8	.....	5	.....	5
1912–13	.....	5.65	.....	8	.....	9	.....	4	.....	2	.....	7	.....	0	.....	3	.....	14	.....	.....	.....	.....	.....	.....	.....	.....
1913–14	.....	7.29	.....	.....	.....	.....	.....	.....	.....	.....	.....	5	.....	5	.....	0	.....	.....	.....	7	.....	15	.....	11	.....	4
1914–15	.....	8.36	.....	4	.....	5	.....	5	.....	0	.....	6	.....	0	.....	11	.....	3	.....	4	.....	21	.....	13	.....	14
1915–16	.....	10.85	.....	11	.....	10	.....	6	.....	10	.....	7	.....	8	.....	5	.....	15	.....	13	.....	16	.....	14	.....	13
Average	.....	7.67	.....	7.55	.....	8.75	.....	4.63	.....	3.89	.....	6.18	.....	2.91	.....	5.60	.....	8.22	.....	7.44	.....	15.89	.....	11.89	.....	10.20
52. Eureka strain: Green grade—																										
1911–12	178– 5	674	17– 5	63	17–10	68	15– 2	60	26– 1	103	13–12	52	17– 1	61	6–10	25	6–14	27	30– 6	112	6–14	26	10–10	38	10– 0	39
1912–13	50– 5	206	0– 5	1	0–12	3	1– 1	4	10– 4	39	5– 8	23	15– 6	63	17– 1	73	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913–14	5– 0	18	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	0	0	0–12	3	1– 2	4	3– 2	11
1914–15	164– 3	587	4– 3	16	1– 0	4	1– 7	6	1–14	7	1– 6	5	9–13	37	1– 2	4	9– 3	33	16– 9	60	36–14	128	62– 4	217	18– 8	70
1915–16	158– 7	610	2– 8	12	1– 8	6	10– 9	42	21–15	88	7– 5	28	4– 3	17	2– 9	10	6– 4	25	24–14	92	42– 1	158	26– 5	99	8– 6	33
1916–17	122–11	495	3–12	16	7– 0	27	4– 0	15	4–13	19	19– 7	78	13– 9	58	8–13	35	.....	.....	16– 9	62	19– 4	80	25– 8	105	0	0
Average	113.16	431.67	5.61	21.60	5.58	21.60	6.44	25.40	12.99	51.20	7.90	31.00	10.00	39.33	6.03	24.50	5.58	21.25	12.62	46.57	21.16	79.00	25.16	92.60	8.00	30.60
Tree-Ripe grade—																										
1911–12	126–12	601	7– 6	29	0	0	0–13	4	0	0	0– 2	1	8–14	40	5–12	27	24– 3	133	40–12	189	2– 0	9	8– 0	30	28–14	139
1912–13	31– 6	163	0– 4	1	0–11	4	1– 4	8	0–14	6	0–12	4	6– 6	29	17–13	92	3– 6	19	.....	.....	.....	.....	.....	.....	.....	.....
1913–14	0–10	2	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	0	0	0– 5	1	0	0	0– 5	1
1914–15	64–12	260	0	0	0	0	0	0	0– 7	2	0	0	2– 5	12	0	0	11– 0	46	7–14	33	14– 5	51	16– 0	62	12–13	54
1915–16	157– 2	745	2–11	14	4– 0	22	4– 6	23	9–11	48	16– 0	65	52– 6	262	0– 6	2	1–14	15	0	0	5– 1	21	52– 8	235	8– 3	38
1916–17	61– 0	280	0–15	6	0–13	5	0– 5	2	2–11	13	0– 5	2	2– 9	14	4–14	20	.....	.....	14–11	60	8– 6	36	24– 8	117	0–15	5
Average	73.60	341.83	2.25	10.00	1.10	6.20	1.35	7.40	2.74	13.80	2.86	12.00	12.08	59.50	4.80	23.50	10.11	53.25	9.04	40.28	6.01	23.60	20.20	88.80	10.23	47.40

Cull grade—																										
1911-12	20- 5	159	....	....	....	....	....	....	....	....	....	....	....	....	....	....	13- 4	113	2-14	17	1- 3	11	0-11	5	2- 5	13
1912-13	107-12	1,073	0-10	5	0- 3	2	1- 2	7	1- 3	13	1- 8	15	2- 0	18	4- 7	35	96-11	978	....	....	....	....	....	....	....	....
1913-14	1- 1	12	....	....	....	....	....	....	....	....	0-11	9	0	0	0	0	....	....	0	0	0	0	0	0	0- 6	3
1914-15	3- 8	24	0	0	0- 3	1	0	0	0	0	0	0	0	0	0- 3	1	0	0	0- 3	2	0-13	6	0-14	6	1- 4	8
1915-16	27- 7	185	1- 6	9	2- 6	22	2- 3	20	2- 2	15	0-13	6	1- 3	7	0- 2	1	0- 9	5	0-10	5	3-13	22	5-11	33	6- 9	40
1916-17	11- 9	91	0- 3	1	0	0	0	0	0	0	0	0	0-12	6	0- 5	2	....	....	1- 6	9	1- 0	6	1- 8	12	6- 7	55
Average	28.60	257.33	0.55	3.75	0.69	6.25	0.83	6.75	0.83	7.00	0.59	6.00	0.79	6.20	1.01	7.80	27.63	274.00	0.73	4.71	1.36	9.00	1.75	11.20	3.39	23.80
Total crop—																										
1911-12	325- 6	1,434	24-11	92	17-10	68	15-15	64	26- 1	103	13-14	53	25-15	101	12- 6	52	44- 5	273	74- 0	318	10- 1	46	19- 5	73	41- 3	191
1912-13	189- 7	1,442	1- 3	7	1-10	9	3- 7	19	12- 5	58	7-12	42	23-12	110	39- 5	200	100-1	997	....	....	....	....	....	....	....	....
1913-14	6-11	32	....	....	....	....	....	....	....	....	0-11	9	0	0	0	0	....	....	0	0	1- 1	4	1- 2	4	3-13	15
1914-15	232- 7	871	4- 3	16	1- 3	5	1- 7	6	2- 5	9	1- 6	5	12- 2	49	1- 5	5	20- 3	79	24-10	95	52- 0	185	79- 2	285	32- 9	132
1915-16	343- 0	1,540	6- 9	35	7-14	50	17- 2	85	33-12	151	24- 2	99	57-12	286	3- 1	13	8-11	45	25- 8	97	50-15	201	84- 8	367	23- 2	111
1916-17	195- 4	866	4-14	23	7-13	32	4- 5	17	7- 8	32	19-12	80	16-14	78	14- 0	57	....	....	32-10	131	28-10	122	51- 8	234	7- 6	60
Average	**215.36**	**1,030.83**	**8.30**	**34.60**	**7.23**	**32.80**	**8.45**	**38.20**	**16.39**	**70.60**	**11.26**	**48.00**	**22.74**	**104.00**	**11.68**	**54.50**	**43.31**	**348.50**	**22.39**	**91.57**	**28.52**	**111.60**	**47.11**	**192.60**	**21.61**	**101.80**
Variable fruits—																										
1914-15	....	34	....	0	....	0	....	1	....	0	....	0	....	2	....	2	....	5	....	2	....	10	....	10	....	2
1915-16	....	28	....	4	....	2	....	0	....	0	....	0	....	1	....	3	....	0	....	4	....	7	....	3	....	4
1916-17	....	83	....	0	....	0	....	0	....	2	....	2	....	3	....	3	....	....	....	26	....	33	....	14	....	0
Average	....	48.33	....	1.33	....	0.67	....	0.33	....	0.67	....	0.67	....	2.00	....	2.67	....	1.67	....	10.67	....	16.67	....	9.00	....	2.00
Average seeds per fruit—																										
1911-12	....	5.77	....	4	....	0	....	1	....	0	....	0	....	6	....	4	....	11	....	4	....	8	....	15	....	9
1912-13	....	6.87	....	11	....	6	....	5	....	3	....	5	....	6	....	6	....	15	....	....	....	....	....	....	....	....
1913-14	....	11.85	....	....	....	....	....	....	....	....	....	15	....	0	....	0	....	....	....	0	....	10	....	16	....	11
1914-15	....	11.44	....	4	....	3	....	4	....	1	....	7	....	3	....	5	....	8	....	19	....	27	....	19	....	10
1915-16	....	12.74	....	13	....	13	....	10	....	8	....	7	....	11	....	11	....	9	....	21	....	19	....	15	....	16
Average	....	9.82	....	9.33	....	7.22	....	5.67	....	3.89	....	6.00	....	7.20	....	7.10	....	10.78	....	15.71	....	17.40	....	16.67	....	11.91
60. Eureka strain:																										
Green grade—																										
1911-12	218- 8	771	14- 3	51	22- 7	83	30-13	114	44- 6	153	24-14	87	26- 6	91	6-11	24	15- 0	52	18- 9	64	5-11	20	6- 7	22	3- 1	10
1912-13	155-11	602	1-12	6	2-10	10	2-13	10	56- 0	208	41-15	163	25- 0	98	25- 5	106	0- 4	1	....	....	....	....	....	....	....	....
1913-14	37- 4	130	....	....	....	....	....	....	....	....	0	0	4- 7	16	5- 3	18	....	....	3- 6	11	2- 7	8	12-2	39	9-11	38
1914-15	282-12	967	12- 8	46	1- 9	6	4- 6	16	3-15	15	21-14	78	39-15	145	3- 4	12	49-14	168	21-14	74	81- 7	267	34-12	114	7- 6	26
1915-16	161- 2	604	3-12	14	15-10	60	22- 2	83	11-15	47	1-11	6	5- 6	21	7-15	30	17-12	66	29- 7	110	26- 7	95	13- 4	49	5-13	23
1916-17	58-11	226	6- 2	25	5- 2	19	1-14	8	3-12	14	2- 7	10	3- 4	14	2-10	10	....	....	7- 4	26	5- 0	19	20-12	79	0- 8	2
Average	152.33	550.00	7.66	28.40	9.48	35.60	12.40	46.20	24.02	87.40	15.47	57.33	17.40	64.17	8.50	33.33	20.72	71.75	11.50	40.71	24.20	81.80	17.46	60.60	5.29	19.80
Tree-Ripe grade—																										
1911-12	23- 1	104	0-11	3	0	0	0- 2	1	0- 6	2	0-11	5	0-10	3	2- 9	16	7- 5	33	5-12	22	2- 2	8	2- 6	9	0- 7	2
1912-13	14- 1	72	0- 4	1	0	0	0	0	1- 2	8	1- 6	6	1- 2	6	10- 3	51	0	0	....	....	....	....	....	....	....	....
1913-14	0-14	4	....	....	....	....	....	....	....	....	0	0	0- 2	1	0	0	....	....	0- 4	1	0- 8	2	0	0	0	0

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
60. Eureka strain—Con. Tree-Ripe grade—Continued																										
1914-15	53- 3	215	0	0	0	0	0	0	0- 5	2	0	0	4-10	21	3- 1	15	10-15	42	13- 5	56	13- 8	51	2-11	10	4-12	18
1915-16	73- 5	330	1- 2	4	3- 2	14	2- 3	11	1- 6	6	8- 0	32	14- 7	68	3-13	23	0- 5	3	0-10	4	4-14	20	31- 5	135	2- 2	10
1916-17	18-15	84	0- 6	2	0-13	5	0	0	2- 8	12	0- 3	1	2- 8	12	0	0	.....	......	3-14	15	2- 9	10	5-12	25	0- 6	2
Average	30.57	134.83	0.49	2.00	0.79	3.80	0.46	2.40	1.14	6.00	1.71	7.33	3.91	18.50	3.27	17.50	4.64	19.50	3.40	14.00	4.71	18.20	8.43	35.80	1.54	6.40
Cull grade—																										
1911-12	4-12	29	.....	.....	.....	.....	.....	.....	.....	......	.....	......	.....	......	.....	......	3- 3	20	0-13	4	0- 6	2	0- 6	3	0	0
1912-13	69-11	650	0- 6	3	0- 7	2	0- 1	1	0-10	6	0-11	6	1- 2	8	19- 8	111	46-14	513	.....	......	.....	......	.....	......	.....	......
1913-14	0- 7	3	.....	.....	.....	.....	.....	.....	.....	......	0- 2	1	0	0	0	0	.....	......	0	0	0	0	0- 2	1	0- 3	1
1914-15	8- 0	43	0- 2	1	0- 2	1	0- 7	2	0- 2	1	0- 3	1	0	0	0	0	0- 4	1	2- 7	12	0-11	5	2-14	15	0-12	4
1915-16	19- 2	114	0- 8	3	0-14	7	0- 8	4	0- 4	2	1- 5	9	0- 6	2	0- 3	1	1-10	9	1- 5	7	1-15	12	7- 1	40	3- 3	18
1916-17	8- 0	56	0- 9	4	0	0	0	0	0- 2	1	0	0	0- 4	3	0	0	.....	......	0- 3	1	1- 2	8	0-10	4	5- 2	35
Average	18.33	149.17	0.39	2.75	0.36	2.50	0.25	1.75	0.28	2.50	0.46	3.40	0.35	2.60	3.94	22.40	12.98	135.75	0.68	3.43	0.83	5.40	2.21	12.60	1.85	11.60
Total crop—																										
1911-12	246- 5	904	14-14	54	22- 7	83	30-15	115	44-12	155	25- 9	92	27- 0	94	9- 4	40	25- 8	105	25- 2	90	8- 3	30	9- 3	34	3- 8	12
1912-13	239- 7	1,324	2- 6	10	3- 1	12	2-14	11	57-12	222	44- 0	175	27- 4	112	55- 0	268	47- 2	514	.....	......	.....	......	.....	......	.....	......
1913-14	38- 9	137	.....	.....	.....	.....	.....	.....	.....	......	0- 2	1	4- 9	17	5- 3	18	.....	......	3-10	12	2-15	10	12- 4	40	9-14	39
1914-15	343-15	1,225	12-10	47	1-11	7	4-13	18	4- 6	18	22- 1	79	44—9	166	6- 5	27	61- 1	211	37-10	142	95-10	323	40- 5	139	12-14	48
1915-16	253- 9	1,048	5- 6	21	19-10	81	24-13	98	13- 9	55	11- 0	47	20- 3	91	11-15	54	19-11	78	31- 6	121	33- 4	127	51-10	224	11- 2	51
1916-17	85-10	366	7- 1	31	5-15	24	1 -14	8	6- 6	27	2-10	11	6- 0	29	2-10	10	.....	......	11- 5	42	8-11	37	27- 2	108	6- 0	39
Average	**201.24**	**834.00**	**8.46**	**32.60**	**10.55**	**41.40**	**13.06**	**50.00**	**25.36**	**95.40**	**17.56**	**67.50**	**21.59**	**84.83**	**15.05**	**69.50**	**38.34**	**227.00**	**15.58**	**58.14**	**29.74**	**105.40**	**28.10**	**109.00**	**8.68**	**37.80**
Variable fruits—																										
1914-15	......	65	.....	0	.....	0	.....	0	.....	1	.....	3	.....	7	.....	1	.....	18	.....	2	.....	13	.....	16	.....	4
1915-16	......	132	.....	9	.....	5	.....	2	.....	5	.....	4	.....	6	.....	6	.....	25	.....	36	.....	0	.....	31	.....	3
1916-17	......	61	.....	0	.....	0	.....	0	.....	0	.....	1	.....	5	.....	3	.....	......	.....	13	.....	16	.....	23	.....	0
Average	......	86.00	.....	3.00	.....	1.67	.....	0.67	.....	2.00	.....	2.67	.....	6.00	.....	3.33	.....	14.33	.....	17.00	.....	9.67	.....	23.33	.....	2.33
Average seeds per fruit—																										
1911-12	......	2.83	.....	3	.....	0	.....	0	.....	1	.....	3	.....	2	.....	2	.....	1	.....	5	.....	4	.....	7	.....	4
1912-13	......	3.86	.....	4	.....	10	.....	0	.....	1	.....	0	.....	5	.....	4	.....	8	.....	......	.....	......	.....	......	.....	......
1913-14	......	7.33	.....	.....	.....	.....	.....	.....	.....	......	.....	9	.....	5	.....	6	.....	......	.....	4	.....	8	.....	9	.....	9

1914-15	.....	6.40	.....	7	.....	4	.....	1	.....	0	.....	1	.....	6	.....	4	.....	4	.....	11	.....	13	.....	13	.....	8
1915-16	.....	9.28	.....	7	.....	6	.....	4	.....	11	.....	5	.....	8	.....	9	.....	12	.....	17	.....	13	.....	9	.....	9
Average	.....	6.23	.....	5.30	.....	6.00	.....	1.56	.....	3.55	.....	3.00	.....	5.67	.....	5.00	.....	6.60	.....	10.30	.....	10.10	.....	10.00	.....	8.00
63. Shade-Tree strain:																										
Green grade—																										
1911-12	205-10	707	18- 6	65	14- 8	55	29- 4	103	49-13	173	14-12	52	30- 3	97	9- 0	32	12-11	42	16-12	55	1- 9	5	6-10	21	2- 2	7
1912-13	139-15	540	5- 3	18	5-10	20	2- 9	10	45- 0	170	41-14	166	33- 9	129	5-12	25	0- 6	2	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	36-14	125	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2- 9	9	2- 5	7	.....	.....	2-13	9	3- 0	9	13- 1	43	13- 2	48
1914-15	281-10	965	9- 3	34	7- 9	28	5-10	21	5- 1	18	32- 3	117	37-12	135	1-11	6	47-10	161	17- 9	57	77- 6	251	30- 5	103	9-11	34
1915-16	168- 1	629	3- 2	11	16-2	60	14- 8	55	18- 4	69	4- 9	17	1- 8	6	10- 5	40	15-10	58	31- 3	114	26-15	99	20- 7	79	5- 8	21
1916-17	98- 1	366	9- 5	35	4- 2	15	0-12	3	2-10	10	6- 8	24	9- 8	35	3- 2	12	.....	.....	17- 2	60	13- 5	50	31- 0	119	0-11	3
Average	155.03	555.33	9.38	32.60	9.59	35.60	10.54	38.40	24.15	88.00	19.98	75.20	19.18	68.50	5.36	20.33	19.08	65.75	12.21	42.14	24.44	82.80	20.29	73.00	6.22	22.60
Tree-Ripe grade—																										
1911-12	25- 4	107	0	0	0	0	0	0	0-11	3	0-12	4	3- 8	15	2- 8	13	10- 4	44	3-14	14	1- 6	5	2- 5	9	0	0
1912-13	8-15	45	0	0	0- 3	1	0	0	1-10	9	0-10	3	1-12	7	4-12	25	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0-15	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	.....	.....	0- 5	1	0- 6	1	0- 4	1	0	0
1914-15	57- 0	227	0	0	0	0	0	0	0- 4	1	0-10	3	5- 2	23	5- 2	23	17- 6	70	7- 4	28	14- 4	51	2-10	11	4- 6	17
1915-16	54- 7	244	0-12	3	4- 2	18	1- 3	6	1- 4	6	9-15	39	10- 2	47	4- 8	24	1- 9	8	0-15	5	1-11	7	13- 2	57	5- 4	24
1916-17	13-11	61	0- 6	2	0	0	0- 3	1	0	0	0- 6	2	1- 5	6	0- 4	1	.....	.....	3-13	14	3- 8	15	3- 0	15	0-14	5
Average	26.71	114.50	0.23	1.00	0.86	3.80	0.28	1.40	0.76	3.80	2.46	10.20	3.64	16.33	2.85	14.33	7.30	30.50	2.31	8.86	4.24	15.80	4.26	18.60	2.10	9.20
Cull grade—																										
1911-12	7- 1	45	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5- 8	33	0-11	5	0- 2	1	0- 9	5	0- 3	1
1912-13	57-15	562	0-10	5	0- 3	1	0- 8	4	0-10	6	1- 9	12	1-11	11	14-3	85	38- 9	438	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	.....	.....	0	0	0	0	0	0	0	0
1914-15	8- 4	46	0- 2	1	0	0	0	0	0	0	0	0	0- 2	1	0- 3	1	3- 1	17	0- 8	2	1- 2	7	2- 4	13	0-14	4
1915-16	13- 4	87	0- 5	2	1- 6	9	0- 5	2	1- 0	7	1- 1	5	0- 9	4	0-11	5	1- 4	12	0- 6	4	0- 8	3	5- 7	32	0- 6	2
1916-17	8- 4	66	0-14	6	0	0	0	0	0	0	0	0	0- 6	3	0- 1	1	.....	.....	0- 6	3	0- 6	3	1-12	12	4- 7	38
Average	15.79	134.33	0.48	3.50	0.39	2.50	0.20	1.50	0.42	3.25	0.66	4.25	0.55	3.80	3.03	18.40	12.09	125.00	0.28	2.00	0.43	2.80	2.00	12.40	1.18	9.00
Total crop—																										
1911-12	237-15	859	18- 6	65	14- 8	55	29- 4	103	50- 8	176	15- 8	56	33-11	112	11- 8	45	28- 7	119	21- 5	74	3- 1	11	9- 8	35	2- 5	8
1912-13	206-13	1,147	5-13	23	6- 0	22	3- 1	14	47- 4	185	44- 1	181	37- 0	147	24-11	135	38-15	440	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	37-13	128	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2- 9	9	2- 5	7	.....	.....	3- 2	10	3- 6	10	13- 5	44	13- 2	48
1914-15	346-14	1,238	9- 5	35	7- 9	28	5-10	21	5- 5	19	32-13	120	43- 0	159	7- 0	30	68- 1	248	25- 5	87	92-12	309	35- 3	127	14-15	55
1915-16	235-12	960	4- 3	16	21-10	87	16- 0	63	20- 8	82	15- 9	61	12- 3	57	15- 8	69	18- 7	78	32- 8	123	29- 2	109	39- 0	168	11- 2	47
1916-17	120- 0	493	10- 9	43	4- 2	15	0-15	4	2-10	10	6-14	26	11- 3	44	3- 7	14	.....	.....	21- 5	77	17- 3	68	35-12	146	6- 0	46
Average	**197.53**	**804.17**	**9.65**	**36.40**	**10.76**	**41.40**	**10.98**	**41.00**	**25.24**	**94.40**	**22.96**	**88.80**	**23.27**	**88.00**	**10.74**	**50.00**	**38.47**	**221.25**	**14.79**	**53.00**	**29.10**	**101.40**	**26.55**	**104.00**	**9.50**	**40.80**
Variable fruits—																										
1914-15	.....	105	.....	5	.....	1	.....	1	.....	3	.....	11	.....	9	.....	1	.....	11	.....	11	.....	19	.....	26	.....	7
1915-16	.....	140	.....	7	.....	1	.....	6	.....	7	.....	4	.....	3	.....	11	.....	20	.....	41	.....	6	.....	32	.....	2
1916-17	.....	127	.....	0	.....	2	.....	0	.....	1	.....	2	.....	7	.....	6	.....	.....	.....	38	.....	33	.....	38	.....	0
Average	.....	124.00	.....	4.00	.....	1.33	.....	2.33	.....	3.67	.....	5.67	.....	6.33	.....	6.00	.....	10.33	.....	30.00	.....	19.33	.....	32.00	.....	3.00

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
63. Shade-Tree strain—Continued.																										
Average seeds per fruit—																										
1911-12	.....	1.05	.....	2	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	6	.....	2	.....	3
1912-13	.....	2.43	.....	4	.....	2	.....	3	.....	4	.....	0	.....	4	.....	0	.....	5	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	3.33	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3	.....	1	.....	.....	.....	3	.....	7	.....	1	.....	5
1914-15	.....	6.24	.....	5	.....	2	.....	7	.....	2	.....	0	.....	2	.....	7	.....	5	.....	3	.....	19	.....	10	.....	7
1915-16	.....	8.44	.....	7	.....	7	.....	7	.....	4	.....	4	.....	8	.....	9	.....	14	.....	14	.....	10	.....	13	.....	5
Average	.....	5.10	.....	5.25	.....	3.38	.....	4.85	.....	2.60	.....	1.20	.....	3.75	.....	4.08	.....	6.80	.....	5.50	.....	11.30	.....	7.30	.....	5.38
66. Dense-Productive strain:																										
Green grade—																										
1911-12	152-12	556	13- 9	49	9- 6	37	16-14	64	27-15	99	8-10	32	13- 7	49	2- 1	8	7-11	29	18- 3	61	10- 6	38	17- 4	61	7- 6	29
1912-13	46- 3	188	1- 5	5	0-13	3	0-14	4	5- 6	18	17- 2	65	9- 8	39	11- 3	54	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	22- 1	74	.....	.....	.....	.....	.....	.....	.....	.....	0- 4	1	0- 9	2	3- 0	10	.....	.....	1- 0	3	1-15	7	9- 1	28	6- 4	23
1914-15	287- 2	1,029	13- 8	54	2-14	12	6-14	26	4- 6	17	22- 0	85	33- 0	125	0-10	2	49- 5	170	47-15	170	67- 7	233	31- 7	108	7-12	27
1915-16	190-10	710	6- 4	23	13- 0	49	19-12	75	10- 2	40	8- 3	31	15- 7	60	11- 4	43	28- 5	102	37- 5	138	24-11	89	10- 5	37	6- 0	23
1916-17	133-14	542	2- 8	10	0- 8	2	2- 8	10	10-15	45	21- 3	87	23- 6	100	9-14	39	.....	.....	23- 0	88	18- 0	70	22- 0	91	0	0
Average	138.77	576.50	7.43	28.20	5.31	20.60	9.38	35.80	11.75	43.80	12.90	50.17	15.89	62.50	6.33	26.00	21.33	75.25	18.20	65.71	24.49	87.40	18.01	65.00	5.48	20.40
Tree-Ripe grade—																										
1911-12	19-12	92	1- 8	7	0	0	0	0	0	0	1-10	10	2-13	15	0-13	5	3-14	17	2-12	11	2-10	11	2-11	11	1- 1	5
1912-13	18- 9	108	0-14	4	0-11	4	0- 4	2	1- 0	5	0- 8	3	1-12	9	13- 8	81	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 3	1	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	0	0	0- 3	1	8- 0	0	0	0
1914-15	63- 7	272	0- 3	1	0	0	0	0	0	0	0- 7	3	6- 9	31	2- 3	11	10- 0	42	15- 8	71	17-14	71	4-12	19	5-15	23
1915-16	42-10	205	2-14	18	1- 1	5	0- 6	2	1- 7	6	5- 8	22	12-11	61	2- 9	16	1-10	9	0- 8	3	1- 6	6	11-12	53	0-14	4
1916-17	42-14	206	0- 5	2	0- 3	1	0	0	0- 3	1	0	0	9- 1	50	1-10	7	.....	.....	7-15	32	4- 6	19	19- 3	94	0	0
Average	31.24	147.33	1.15	6.40	0.39	2.00	0.13	0.80	0.53	2.40	1.34	6.33	5.48	27.66	3.45	20.00	3.88	17.00	3.81	16.71	5.29	21.60	7.68	35.40	1.58	6.40
Cull grade—																										
1911-12	7- 4	61	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3-11	35	1- 0	8	0- 9	3	1-12	11	0- 4	4
1912-13	96-12	1,081	0- 8	4	0- 4	2	1- 6	9	1- 2	13	0- 8	3	3- 3	20	15-14	109	73-15	921	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 9	4	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	0	0	0	0	0- 6	3	0- 3	1
1914-15	10- 4	59	0	0	0	0	0- 5	2	0	0	0- 6	2	0- 3	1	0-15	6	1-14	10	1- 7	8	1- 5	9	2- 9	14	1- 4	7

1915-16	12- 4	81	0-14	6	0- 8	4	0- 9	4	0- 5	2	0- 4	2	0- 9	5	1- 0	6	0	0	0- 7	4	1- 6	7	4- 2	28	2- 4	13
1916-17	15- 3	117	0-14	6	0	0	0	0	0	0	0	0	1-11	15	0	0	.....	.....	0- 6	4	0-14	7	4- 0	28	7- 6	57
Average	23.71	233.83	0.56	4.00	0.19	1.50	0.56	2.34	0.36	3.75	0.23	1.40	1.13	8.20	3.56	24.20	19.88	241.50	0.46	3.43	0.83	5.20	2.56	16.80	2.26	16.40
Total crop—																										
1911-12	179-12	709	15- 1	56	9- 6	37	16-14	64	27-15	99	10- 4	42	16- 4	64	2-14	13	15- 4	81	21-15	80	13- 9	52	21-11	83	8-11	38
1912-13	161- 8	1,377	2-11	13	1-12	9	2- 8	15	7- 8	36	18- 2	71	14- 7	68	40- 9	244	73-15	921	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	22-13	79	.....	.....	.....	.....	.....	.....	.....	.....	0- 4	1	0- 9	2	3- 0	10	.....	.....	1- 0	3	2- 2	8	9- 7	31	6- 7	24
1914-15	360-13	1,360	13-11	55	2-14	12	7- 3	28	4- 6	17	22-13	90	39-12	157	3-12	19	61- 3	222	64-14	249	86-10	313	38-12	141	14-15	57
1915-16	245- 8	996	10- 0	47	14- 9	58	20-11	81	11-14	48	13-15	55	28-11	126	14-13	65	29-15	111	38- 4	145	27- 7	102	26- 3	118	9- 2	40
1916-17	191-15	865	3-11	18	0-11	3	2- 8	10	11- 2	46	21- 3	87	34- 2	165	11- 8	46	.....	.....	31- 5	124	23- 4	96	45- 3	213	7- 6	57
Average	**193.72**	**897.67**	**9.03**	**37.80**	**5.85**	**23.80**	**9.95**	**39.60**	**12.56**	**49.20**	**14.43**	**57.67**	**22.30**	**97.00**	**12.75**	**66.17**	**45.08**	**333.75**	**22.48**	**85.86**	**30.60**	**114.20**	**28.25**	**117.20**	**9.31**	**43.20**
Variable fruits—																										
1914-15	.....	69	.....	6	.....	0	.....	1	.....	0	.....	2	.....	6	.....	1	.....	7	.....	13	.....	14	.....	13	.....	6
1915-16	.....	151	.....	19	.....	1	.....	3	.....	3	.....	5	.....	18	.....	12	.....	34	.....	33	.....	12	.....	10	.....	1
1916-17	.....	140	.....	1	.....	0	.....	0	.....	1	.....	8	.....	21	.....	4	.....	0	.....	31	.....	26	.....	48	.....	0
Average	.....	120.00	.....	8.67	.....	0.33	.....	1.33	.....	1.33	.....	5.00	.....	15.00	.....	5.67	.....	13.67	.....	25.67	.....	17.33	.....	23.67	.....	2.33
Average seeds per fruit—																										
1911-12	.....	7.14	.....	4	.....	4	.....	0	.....	0	.....	5	.....	6	.....	7	.....	6	.....	15	.....	12	.....	8	.....	12
1912-13	.....	4.91	.....	6	.....	9	.....	8	.....	2	.....	0	.....	5	.....	5	.....	1	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	8.40	.....	.....	.....	.....	.....	.....	.....	.....	.....	17	.....	11	.....	8	.....	.....	.....	2	.....	6	.....	11	.....	7
1914-15	.....	6.57	.....	1	.....	0	.....	1	.....	0	.....	1	.....	2	.....	5	.....	15	.....	4	.....	12	.....	13	.....	13
1915-16	.....	8.37	.....	7	.....	9	.....	11	.....	8	.....	4	.....	6	.....	8	.....	11	.....	8	.....	11	.....	9	.....	10
Average	.....	7.05	.....	4.70	.....	7.25	.....	6.44	.....	3.63	.....	3.25	.....	5.17	.....	6.25	.....	10.13	.....	7.44	.....	10.60	.....	10.60	.....	10.40
71. Pear-Shape strain:																										
Green grade—																										
1911-12	178-10	638	6- 8	24	9- 8	37	23-12	86	48-13	182	17- 0	59	49- 3	166	5- 6	20	8- 0	28	7- 8	25	0-14	3	0- 5	1	1-13	7
1912-13	83- 7	335	0-13	3	1- 7	5	2-14	11	23-13	87	12- 7	49	17-15	71	23-14	108	0- 4	1	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	21- 1	74	.....	.....	.....	.....	.....	.....	.....	.....	1- 2	5	5- 4	18	4-10	15	.....	.....	3- 1	10	0- 4	1	1-12	6	5- 0	19
1914-15	187- 7	705	14- 0	53	21-13	88	21-11	86	12- 3	47	37- 1	139	45- 5	170	2- 0	8	9- 6	32	2-12	10	8- 3	28	9- 1	30	4- 0	14
1915-16	169- 1	623	2- 2	8	12-11	45	36- 5	130	31- 7	113	13-15	52	11- 7	43	10-13	42	12- 1	46	12-10	49	11- 2	38	9-14	38	4-10	19
1916-17	69-14	304	2- 2	8	3- 5	12	2- 7	10	13- 3	52	17-14	73	26- 1	130	0	0	.....	.....	0-14	3	1-11	7	2- 5	9	0	0
Average	118.25	446.50	5.11	19.20	9.75	37.40	17.41	64.60	25.89	96.20	16.57	62.83	25.86	99.67	7.78	32.17	7.42	26.75	3.83	13.85	4.43	15.40	4.66	16.80	3.09	11.80
Tree-Ripe grade—																										
1911-12	50- 7	219	0-10	3	0	0	0	0	0- 4	1	1-13	9	11-15	50	6- 0	31	15-14	71	10-14	42	0-14	4	1-13	7	0- 6	1
1912-13	17- 5	87	0	0	0-11	3	0	0	2- 2	12	0	0	3- 7	16	11- 1	56	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	5- 1	19	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	2- 3	8	.....	.....	1-14	7	0	0	0- 4	1	0-12	3
1914-15	95- 1	471	0	0	0	0	0	0	2-12	15	4- 3	20	64- 6	337	1-14	13	2- 4	9	4-14	21	5-14	22	5- 4	19	3-10	15
1915-16	58- 4	277	0-15	4	1-12	9	2- 5	10	2- 7	10	13-12	56	26- 0	135	2- 2	11	0- 9	3	0- 6	2	2- 5	9	5-11	28	0	0
1916-17	96- 7	578	2- 0	10	0- 6	2	0- 8	3	1-12	9	21- 0	116	55-11	356	0	0	.....	.....	0- 8	2	0- 4	1	14- 6	79	0	0
Average	53.76	275.17	0.71	3.40	0.56	2.80	0.56	2.60	1.86	9.40	6.79	33.50	26.91	149.00	3.88	19.83	4.67	20.75	2.64	10.57	1.86	7.20	5.48	26.80	0.95	3.80

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
71. Pear-Shape strain—Continued.																										
Cull grade—																										
1911-12	7- 9	49	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	6-14	45	0- 2	1	0	0	0- 3	1	0- 6	2
1912-13	46- 8	473	0 -2	1	0	0	0- 2	1	0- 8	4	0- 5	3	0-13	5	26- 5	170	18- 5	289	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 4	2	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	0- 4	2	0	0	0	0	0	0
1914-15	7- 2	48	0	0	0	0	0	0	0- 5	3	0- 6	3	1- 8	11	0-10	5	0	0	1- 2	8	0-11	4	1- 0	5	1- 8	9
1915-16	9-11	59	0- 9	7	0- 3	1	1- 0	6	0-13	4	1- 6	6	0	0	0- 5	2	1-10	10	0- 3	2	0-14	5	2- 6	14	0- 6	2
1916-17	6- 2	62	0-14	4	0	0	0	0	0- 3	2	0- 8	5	2-15	35	0	0	.....	.....	0- 2	1	0- 5	3	0-11	9	0- 8	3
Average	12.88	115.50	0.39	3.00	0.75	0.25	0.28	1.75	0.45	3.25	0.51	3.40	1.05	10.20	5.45	35.40	6.70	86.00	0.26	2.00	0.38	2.40	0.85	5.80	0.55	3.20
Total crop—																										
1911-12	236-10	906	7- 2	27	9- 8	37	23-12	86	49- 1	183	18-13	68	61- 2	216	11- 6	51	30-12	144	18- 8	68	1-12	7	2- 5	9	2- 9	10
1912-13	147- 4	895	0-15	4	2- 2	8	3- 0	12	26- 7	103	12-12	52	22- 3	92	61- 4	334	18- 9	290	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	26- 6	95	.....	.....	.....	.....	.....	.....	.....	.....	1- 2	5	5- 4	18	6-13	23	.....	.....	5- 3	19	0- 4	1	2- 0	7	5-12	22
1914-15	289-10	1,224	14- 0	53	21-13	88	21-11	86	15- 4	65	41-10	162	111-3	518	4- 8	26	11-10	41	8-12	39	14-12	54	15- 5	54	9- 2	38
1915-16	237- 0	959	3-10	19	14-10	55	39-10	146	34-11	127	29- 1	114	37- 7	178	13- 4	55	14- 4	59	13- 3	53	14- 5	52	17-15	80	5- 0	21
1916-17	172- 7	944	5- 0	22	3-11	14	2-15	13	15- 2	63	39- 6	194	84-11	521	0	0	.....	.....	1- 8	6	2- 4	11	17- 6	97	0- 8	3
Average	**184.89**	**837.17**	**6.14**	**25.00**	**10.22**	**40.40**	**18.20**	**68.60**	**28.11**	**108.20**	**23.79**	**99.17**	**53.65**	**257.17**	**16.20**	**81.50**	**18.80**	**133.50**	**6.73**	**26.42**	**6.66**	**25.00**	**10.99**	**49.40**	**4.59**	**18.80**
Variable fruits—																										
1914-15	.....	536	.....	39	.....	68	.....	32	.....	22	.....	48	.....	197	.....	7	.....	21	.....	20	.....	25	.....	31	.....	26
1915-16	.....	522	.....	11	.....	45	.....	116	.....	88	.....	47	.....	74	.....	16	.....	18	.....	18	.....	21	.....	50	.....	18
1916-17	.....	518	.....	16	.....	14	.....	10	.....	43	.....	97	.....	272	.....	0	.....	.....	.....	3	.....	7	.....	56	.....	0
Average	.....	525.33	.....	22.00	.....	42.33	.....	52.67	.....	51.00	.....	64.00	.....	181.00	.....	7.67	.....	13.00	.....	13.67	.....	17.67	.....	45.67	.....	14.67
Average seeds per fruit—																										
1911-12	.....	0.77	.....	1	.....	0	.....	0	.....	2	.....	0	.....	0	.....	0	.....	0	.....	0	.....	3	.....	0	.....	3
1912-13	.....	.84	.....	2	.....	3	.....	0	.....	0	.....	0	.....	0	.....	0	.....	3	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	1.67	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	4	.....	0	.....	.....	.....	1	.....	1	.....	4	.....	3
1914-15	.....	1.45	.....	1	.....	1	.....	4	.....	1	.....	0	.....	0	.....	2	.....	0	.....	2	.....	2	.....	0	.....	4
1915-16	.....	3.24	.....	3	.....	4	.....	2	.....	4	.....	2	.....	1	.....	1	.....	1	.....	7	.....	4	.....	4	.....	5
Average	.....	1.77	.....	2.00	.....	2.85	.....	1.29	.....	1.82	.....	0.55	.....	0.55	.....	0.85	.....	1.00	.....	2.55	.....	2.89	.....	2.10	.....	3.67

72. Eureka strain:																										
Green grade—																										
1911-12	190- 1	705	14- 8	54	10-11	42	22- 0	83	34- 6	132	18- 3	69	20- 5	75	11- 8	43	10-10	39	23-12	81	4-14	18	15- 4	52	4- 0	1.
1912-13	88- 8	359	2- 9	9	1- 7	5	2-14	9	17- 6	66	22- 3	88	19- 5	80	22- 8	101	0- 4	1	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	4- 0	13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0- 8	2	0-10	2	.....	.....	0- 6	1	0-11	2	0-11	2	1- 2	4
1914-15	222-13	785	1- 4	5	0- 4	1	4- 7	17	6- 0	23	20- 7	78	27- 5	104	0- 6	1	43- 2	146	53- 4	181	28- 4	99	33- 3	112	4-15	18
1915-16	133- 1	503	0-12	3	4-12	17	8-10	33	3-13	14	5-15	21	10-13	41	19- 0	75	19-14	74	17- 2	65	27- 0	100	11-12	46	3-10	14
1916-17	114-14	463	1-12	7	2- 4	10	0-12	3	2-15	12	9- 2	38	13- 2	54	11-12	45	.....	.....	24-11	95	18- 0	72	30- 8	127	0	0
Average	125.55	471.33	4.16	15.60	3.88	15.00	7.74	29.00	12.90	49.40	15.18	58.80	15.23	59.33	10.96	44.50	18.47	65.00	17.03	60.43	15.76	58.20	18.28	67.80	2.74	10.60
Tree-Ripe grade—																										
1911-12	50-11	226	0- 2	1	0	0	0	0	0- 8	2	1- 9	10	5-13	27	5- 4	25	14-14	70	9- 5	35	5-10	23	6- 4	26	1- 6	7
1912-13	24- 2	130	0- 2	1	0- 4	2	0	0	3- 9	20	1- 2	5	4- 2	20	14-15	82	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 5	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	.....	.....	0	0	0	0	0	0	0- 5	1
1914-15	58- 2	241	0	0	0	0	0	0	0- 4	1	0- 2	1	5- 0	23	2- 6	11	14- 7	58	17- 6	72	13- 0	53	2- 4	9	3- 5	13
1915-16	32- 1	160	0- 7	2	0	0	0- 9	3	1- 1	5	1- 3	5	8- 6	44	5- 0	30	0- 6	3	0- 1	1	1-14	8	11- 8	52	1-10	7
1916-17	50- 3	230	0- 3	1	0	0	0	0	0- 3	1	0- 8	3	10- 3	53	3- 4	13	.....	.....	8- 2	32	7- 4	32	20- 8	95	0	0
Average	35.92	164.67	0.18	1.00	0.05	0.40	0.11	0.60	1.11	5.80	0.90	4.80	5.58	27.83	5.14	26.83	7.42	32.75	4.98	20.00	5.55	23.20	8.10	36.40	1.33	5.60
Cull grade—																										
1911-12	12- 3	84	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7- 0	51	2- 0	12	1- 3	8	0- 6	4	1-10	9
1912-13	98-10	972	0-12	4	1- 0	7	0-13	5	0-10	7	1- 2	13	2-11	17	23- 4	149	68- 6	770	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	.....	.....	0	0	0	0	0	0	0	0
1914-15	5- 7	31	0	0	0	0	0	0	0- 3	1	0- 4	2	0	0	0- 4	1	1- 1	6	0-14	5	1- 4	7	1- 2	6	0- 7	3
1915-16	9- 3	54	0- 8	4	0- 6	2	0- 9	4	0- 7	3	0	0	0- 3	1	0- 6	2	0	0	0- 3	1	0- 4	2	3- 4	19	3- 1	16
1916-17	13- 9	97	0-14	6	0	0	0	0	0	0	0- 1	1	0	0	0- 2	1	.....	.....	0-12	7	1- 8	11	4- 0	26	6- 4	45
Average	23.17	206.33	0.53	3.50	0.36	2.25	0.34	2.25	0.31	2.75	0.36	4.00	0.58	3.60	4.80	30.60	19.11	206.75	0.54	3.57	0.84	5.60	1.75	11.00	2.28	14.60
Total crop—																										
1911-12	252-15	1,015	14-10	55	10-11	42	22- 0	83	34-14	134	19-12	79	26- 2	102	16-12	68	32- 8	160	35- 1	128	11-11	49	21-14	82	7- 0	33
1912-13	211- 4	1,461	3- 7	14	2-11	14	3-11	14	21- 9	93	24- 7	106	26- 2	117	60-11	332	68-10	771	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	4- 5	14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0- 8	2	0-10	2	.....	.....	0- 6	1	0-11	2	0-11	2	1- 7	5
1914-15	286- 6	1,057	1- 4	5	0- 4	1	4- 7	17	6- 7	25	20-13	81	32- 5	127	3- 0	13	58-10	210	71- 8	258	42- 8	159	36- 9	127	8-11	34
1915-16	174- 5	717	1-11	9	5- 2	19	9-12	40	5- 5	22	7- 2	26	19- 6	86	24- 6	107	20- 4	77	17- 6	67	29- 2	110	26- 8	117	8- 5	37
1916-17	178-10	790	2-13	14	2- 4	10	0-12	3	3- 2	13	9-11	42	23- 5	107	15- 2	59	.....	.....	33- 9	134	26-12	115	55- 0	248	6- 4	45
Average	**184.64**	**842.33**	**4.76**	**19.40**	**4.20**	**17.20**	**8.13**	**31.40**	**14.26**	**57.40**	**16.36**	**66.80**	**21.29**	**90.17**	**20.09**	**96.83**	**45.00**	**304.50**	**22.55**	**84.00**	**22.15**	**87.00**	**28.13**	**115.20**	**6.34**	**30.80**
Variable fruits—																										
1914-15	.....	60	.....	4	.....	0	.....	0	.....	1	.....	6	.....	1	.....	0	.....	8	.....	12	.....	4	.....	18	.....	6
1915-16	.....	159	.....	4	.....	0	.....	2	.....	2	.....	5	.....	11	.....	34	.....	33	.....	20	.....	27	.....	18	.....	3
1916-17	.....	172	.....	0	.....	0	.....	1	.....	1	.....	7	.....	21	.....	8	.....	.....	.....	38	.....	53	.....	43	.....	0
Average	.....	130.33	.....	2.67	.....	0	.....	1.00	.....	1.33	.....	6.00	.....	11.00	.....	14.00	.....	13.67	.....	23.33	.....	28.00	.....	26.33	.....	3.00
Average seeds per fruit—																										
1911-12	.....	4.14	.....	8	.....	0	.....	5	.....	3	.....	4	.....	1	.....	0	.....	8	.....	7	.....	6	.....	1	.....	6
1912-13	.....	4.82	.....	5	.....	5	.....	10	.....	3	.....	1	.....	0	.....	11	.....	3	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	7.57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	6	.....	4	.....	.....	.....	.....	2	8	.....	11	.....	8

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
72. Eureka strain—Con. Average seeds per fruit—Contd.																										
1914-15	.....	5.00	.....	12	.....	0	.....	0	.....	0	.....	1	.....	1	.....	1	.....	4	.....	1	.....	15	.....	13	.....	9
1915-16	.....	9.22	.....	8	.....	8	.....	8	.....	8	.....	8	.....	5	.....	10	.....	11	.....	10	.....	11	.....	12	.....	9
Average	.....	6.19	.....	7.44	.....	4.71	.....	7.14	.....	3.82	.....	3.30	.....	2.09	.....	5.75	.....	6.56	.....	5.78	.....	11.22	.....	9.56	.....	8.40
81. Small-Open strain: Green grade—																										
1911-12	198-11	729	14-12	56	12-15	51	24- 4	93	41-14	154	21-10	79	21- 2	78	10-11	40	11- 9	40	18- 6	64	5-10	20	11- 5	38	4- 9	16
1912-13	85- 0	342	2- 7	9	3- 3	12	2- 7	10	15- 8	62	33- 8	133	17- 4	71	10-11	45	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	8- 5	30	.....	.....	.....	.....	.....	.....	.....	.....	0- 4	1	0	0	3- 0	11	.....	.....	0-15	3	0	0	2- 6	8	1-12	7
1914-15	170-14	629	3- 3	12	1- 2	4	2- 6	8	1- 5	5	5- 3	21	23- 5	94	0-14	3	19- 8	71	30-12	112	49- 6	178	24- 0	86	9-14	35
1915-16	118-15	464	2- 4	9	6-12	25	12-10	51	17-14	71	0-13	3	1- 0	4	3- 8	15	5- 0	20	19-11	76	21- 5	81	22- 3	86	5-15	23
1916-17	73-15	296	3- 4	13	4- 0	16	3- 0	12	4- 2	16	6-14	28	9-11	41	3- 9	15	.....	.....	7-12	30	13- 9	52	18- 2	73	0	0
Average	109.29	415.00	5.18	19.80	5.60	21.60	8.94	34.80	16.14	61.60	11.38	44.17	12.06	48.00	5.39	21.50	9.01	32.75	11.07	40.71	17.97	66.20	15.60	58.20	4.43	16.20
Tree-Ripe grade—																										
1911-12	28- 0	123	0- 3	1	0	0	0	0	0	0	0- 3	1	2-11	14	2- 6	12	6-10	30	10- 6	42	0-15	4	2-14	11	1-12	8
1912-13	33- 6	168	0	0	0- 2	1	0	0	2- 9	12	3-10	17	3- 3	15	23-14	123	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 4	1	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	0	0	0	0	0	0	0- 4	1
1914-15	60- 5	263	0	0	0	0	0	0	0	0	0- 5	2	6- 2	32	0	0	16- 6	74	15- 8	66	15- 0	62	3- 6	13	3-10	14
1915-16	117- 9	561	3- 2	15	3- 8	18	6-11	33	3- 0	14	16-14	69	41- 2	203	4- 8	32	1- 2	6	1- 0	6	5- 6	22	28-15	133	2- 5	10
1916-17	26-13	121	0- 6	2	0	0	0	0	0	0	0- 6	2	2- 9	14	1- 8	6	.....	.....	4- 6	18	5- 0	21	12-10	58	0	0
Average	44.39	206.17	0.74	3.60	0.73	3.80	1.34	6.60	1.11	5.20	3.56	15.17	9.28	46.33	5.38	28.83	6.03	27.50	4.46	18.85	5.26	21.80	9.56	43.00	1.59	6.60
Cull grade—																										
1911-12	6-15	45	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4- 0	26	1-10	9	0- 8	3	0- 6	4	0- 7	3
1912-13	110-10	987	1- 0	5	0- 6	6	0-10	4	1- 0	7	0-13	11	1- 0	9	27-11	179	78- 2	766	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 3	1	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	0	0	0	0	0- 3	1	0	0
1914-15	4- 3	23	0- 3	1	0	0	0	0	0	0	0	0	0	0	0	0	1- 2	7	0- 7	2	0- 6	2	1- 3	7	0-14	4
1915-16	26-11	170	1- 1	7	1- 8	13	0- 8	4	2- 0	14	0-13	6	0- 2	1	0-13	5	0- 6	3	0- 8	4	5- 5	30	11- 3	65	2- 8	18
1916-17	4-10	33	0- 3	1	0	0	0	0	0	0	0	0	1-11	13	0	0	.....	.....	0- 4	2	0- 3	1	0- 8	4	1-13	12
Average	25.54	209.83	0.81	3.50	0.47	4.75	0.28	2.00	0.75	5.25	0.33	3.40	0.56	4.60	5.70	36.80	20.91	200.50	0.40	2.43	1.28	7.20	2.69	16.20	1.13	7.40

Total crop—																										
1911-12	233-10	897	14-15	57	12-15	51	24-4	93	41-14	154	21-13	80	23-13	92	13-1	52	22-3	96	30-6	115	7-1	27	14-9	53	6-12	27
1912-13	229-0	1,497	3-7	14	3-11	19	3-1	14	19-1	81	37-15	161	21-7	95	62-4	347	78-2	766	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	8-12	32	.....	.....	.....	.....	.....	.....	.....	.....	0-4	1	0	0	3-0	11	.....	.....	0-15	3	0	0	2-9	9	2-0	8
1914-15	235-6	915	3-6	13	1-2	4	2-6	8	1-5	5	5-8	23	29-7	126	0-14	3	37-0	152	46-11	180	64-12	242	28-9	106	14-6	53
1915-16	263-3	1,195	6-7	31	11-12	56	19-13	88	22-14	99	18-8	78	42-4	208	8-13	52	6-8	29	21-3	86	32-0	133	62-5	284	10-12	51
1916-17	105-6	450	3-13	16	4-0	16	3-0	12	4-2	16	7-4	30	13-15	68	5-1	21	.....	.....	12-6	50	18-12	74	31-4	135	1-13	12
Average	**179.22**	**831.00**	**6.40**	**26.20**	**6.70**	**29.20**	**10.50**	**43.00**	**17.85**	**71.00**	**15.21**	**62.17**	**21.81**	**98.17**	**15.51**	**81.00**	**35.95**	**260.75**	**15.93**	**62.00**	**24.51**	**95.20**	**27.85**	**117.40**	**7.14**	**30.20**
Variable fruits—																										
1914-15	.....	33	.....	0	.....	0	.....	0	.....	1	.....	1	.....	0	.....	1	.....	1	.....	5	.....	6	.....	13	.....	5
1915-16	.....	59	.....	5	.....	1	.....	3	.....	1	.....	0	.....	1	.....	6	.....	3	.....	9	.....	2	.....	23	.....	5
1916-17	.....	73	.....	0	.....	0	.....	1	.....	0	.....	0	.....	8	.....	3	.....	.....	.....	11	.....	24	.....	26	.....	0
Average	.....	55.00	.....	1.67	.....	0.33	.....	1.33	.....	0.67	.....	0.33	.....	3.00	.....	3.33	.....	1.33	.....	8.33	.....	10.67	.....	20.67	.....	3.33
Average seeds per fruit—																										
1911-12	.....	4.33	.....	5	.....	2	.....	0	.....	0	.....	2	.....	0	.....	6	.....	4	.....	7	.....	7	.....	5	.....	10
1912-13	.....	4.75	.....	10	.....	4	.....	6	.....	2	.....	0	.....	7	.....	4	.....	10	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	8.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	15	.....	.....	.....	5	.....	.....	.....	5	.....	0	.....	5	.....	11
1914-15	.....	7.76	.....	4	.....	0	.....	0	.....	0	.....	2	.....	7	.....	8	.....	5	.....	12	.....	15	.....	12	.....	9
1915-16	.....	11.42	.....	14	.....	10	.....	6	.....	12	.....	6	.....	5	.....	9	.....	15	.....	16	.....	16	.....	15	.....	12
Average	.....	7.77	.....	8.67	.....	5.38	.....	4.43	.....	5.38	.....	3.73	.....	5.10	.....	6.30	.....	8.67	.....	11.56	.....	13.25	.....	10.40	.....	10.50
88. Eureka strain:																										
Green grade—																										
1911-12	102-8	385	8-13	33	6-8	25	9-1	34	18-6	70	9-1	34	11-14	43	4-0	15	5-2	19	13-9	53	6-6	23	4-15	17	4-13	19
1912-13	19-12	80	0	0	0-14	4	0-12	3	0-15	4	2-5	9	6-14	27	8-0	33	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	2-14	10	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	0	0	0	0	1-14	6	1-0	4
1914-15	185-6	661	7-2	28	1-11	7	5-10	20	2-0	8	3-8	14	8-12	33	10-15	38	25-6	89	24-15	90	34-10	119	43-1	150	17-12	65
1915-16	162-9	617	0-14	4	4-14	19	6-11	26	14-2	54	3-13	15	2-11	10	4-12	18	10-1	39	47-9	178	49-2	184	13-11	53	4-5	17
1916-17	82-0	334	4-8	19	2-0	8	2-14	11	4-2	17	7-1	29	12-9	57	1-3	5	.....	.....	9-10	37	21-14	85	16-3	66	0	0
Average	92.51	347.83	4.26	16.80	3.19	12.60	5.00	18.80	7.91	30.60	4.29	16.83	7.13	28.33	4.81	18.17	10.14	36.75	13.67	51.14	22.40	82.20	15.95	58.40	5.58	21.00
Tree-Ripe grade—																										
1911-12	79-11	400	2-11	12	0	0	0	0	0-2	1	0	0	13-2	62	3-9	16	24-7	138	11-6	54	1-4	6	6-12	27	16-6	84
1912-13	13-7	69	0	0	0-14	4	0-6	2	0-4	2	0-11	4	2-13	13	7-3	37	1-4	7	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0-0	0	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	0	0	0	0	0	0	0	0
1914-15	93-15	385	0	0	0	0	0	0	0	0	0	0	1-1	5	11-2	47	24-9	104	20-8	88	11-10	43	16-13	64	8-4	34
1915-16	105-12	503	2-4	10	1-2	6	1-8	7	2-11	12	15-8	68	11-10	63	4-6	25	2-0	15	1-8	9	4-1	17	54-9	249	4-9	22
1916-17	57-7	291	0-5	2	0-5	2	0-5	2	2-8	14	0-12	4	17-0	104	1-6	6	.....	.....	7-12	31	7-12	35	19-6	91	0	0
Average	58.38	274.67	1.05	4.80	0.46	2.40	0.44	2.20	1.11	5.80	2.82	12.67	7.60	41.17	4.60	21.83	13.06	66.00	5.88	26.00	4.94	20.20	19.50	86.20	5.84	28.00
Cull grade—																										
1911-12	14-0	127	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7-9	75	2-3	15	1-1	8	1-12	14	1-7	15
1912-13	60-13	738	0-11	5	1-7	12	0-2	1	0-10	7	0-3	3	0-5	3	0-11	6	56-12	701	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0-2	1	.....	.....	.....	.....	.....	.....	.....	.....	0-2	1	0	0	0	0	.....	.....	0	0	0	0	0	0	0	0
1914-15	11-8	63	0-7	2	0	0	0	0	0-13	5	0	0	0	0	0	0	0-9	5	0-7	3	0-14	5	6-10	33	1-12	10

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
88. Eureka strain—Con.																										
Cull grade—Contd.																										
1915-16	16- 5	104	0-12	5	0- 2	1	0- 7	4	0- 7	3	0	0	0- 3	1	0- 2	1	2- 4	22	0- 6	2	1-15	11	6- 2	35	3- 9	19
1916-17	6- 6	53	0- 6	3	0	0	0	0	0	0	0	0	0-13	9	0	0	.....	......	0-12	6	1-12	13	1- 8	13	1- 3	9
Average	18.18	181.00	0.56	3.75	0.39	3.25	0.14	1.25	0.47	3.75	0.62	0.80	0.26	2.60	0.16	1.40	16.78	200.75	0.54	3.71	1.12	7.40	3.20	19.00	1.59	10.60
Total crop—																										
1911-12	196- 3	912	11- 8	45	6- 8	25	9- 1	34	18- 3	71	9- 1	34	25- 0	105	7- 9	31	37- 2	232	27- 2	122	8-11	37	13- 7	58	22-10	118
1912-13	94- 0	887	0-11	5	3- 3	20	1- 4	6	1-18	13	3- 3	16	10- 0	43	15-14	76	58- 0	708	.....	......	.....	......	.....	......	.....	......
1913-14	3- 0	11	.....	.....	.....	.....	.....	.....	.....	......	0- 2	1	0	0	0	0	.....	......	0	0	0	0	1-14	6	1- 0	4
1914-15	290-13	1,109	7- 9	30	1-11	7	5-10	20	2-13	13	3- 8	14	9-13	38	22- 1	85	50- 8	198	45-14	181	47- 2	167	66- 8	247	27-12	109
1915-16	284-10	1,224	3-14	19	6- 2	26	8-10	37	17- 4	69	19- 5	83	14- 8	74	9- 4	44	14- 5	76	49- 7	189	55- 2	212	74- 6	337	12- 7	58
1916-17	145-13	678	5- 3	24	2- 5	10	3- 3	13	6-10	31	7-13	33	30- 6	170	2- 9	11	.....	......	18- 2	74	31- 6	133	37- 1	170	1- 3	9
Average	**169.07**	803.50	**5.76**	**24.60**	**3.96**	**17.60**	**5.55**	**22.00**	**9.40**	39.40	**7.17**	30.17	**14.95**	71.67	**9.55**	**41.17**	**39.98**	**303.50**	**20.08**	80.86	**28.46**	**109.80**	**38.65**	**163.60**	**13.00**	**59.60**
Variable fruits—																										
1914-15	......	60	.....	1	.....	0	.....	1	.....	0	.....	3	.....	0	.....	4	.....	13	.....	3	.....	7	.....	26	.....	2
1915-16	......	81	.....	4	.....	1	.....	0	.....	2	.....	1	.....	2	.....	7	.....	6	.....	35	.....	7	.....	13	.....	3
1916-17	......	67	.....	0	.....	0	.....	0	.....	0	.....	3	.....	9	.....	0	.....	......	.....	12	.....	26	.....	17	.....	0
Average	......	69.33	.....	1.67	.....	0.33	.....	0.33	.....	0.67	.....	2.33	.....	3.67	.....	3.67	.....	6.33	.....	16.67	.....	13.33	.....	18.67	.....	1.67
Average seeds per fruit—																										
1911-12	......	7.19	.....	6	.....	0	.....	0	.....	5	.....	0	.....	1	.....	2	.....	6	.....	9	.....	10	.....	20	.....	14
1912-13	......	5.82	.....	9	.....	8	.....	6	.....	5	.....	2	.....	0	.....	10	.....	8	.....	......	.....	......	.....	......	.....	......
1913-14	......	3.33	.....	......	.....	......	.....	......	.....	......	.....	2	.....	0	.....	0	.....	......	.....	0	.....	0	.....	0	.....	8
1914-15	......	6.92	.....	4	.....	5	.....	5	.....	0	.....	1	.....	4	.....	3	.....	5	.....	12	.....	10	.....	16	.....	6
1915-16	......	12.03	.....	13	.....	11	.....	10	.....	10	.....	7	.....	8	.....	9	.....	17	.....	9	.....	14	.....	15	.....	14
Average	......	8.32	.....	8.75	.....	8.13	.....	6.75	.....	5.60	.....	3.13	.....	3.90	.....	6.80	.....	9.46	.....	10.38	.....	11.63	.....	15.00	.....	10.89
93. Shade-Tree strain:																										
Green grade—																										
1911-12	149- 4	550	13-10	61	11- 3	43	30-11	108	38- 5	132	19-13	68	10-10	51	6- 8	24	3- 8	12	4-15	17	2-10	9	4- 0	13	3- 7	12
1912-13	146-14	581	2- 9	10	3- 4	10	0- 9	2	44-13	171	41- 2	165	35- 1	142	19- 8	81	0	0	.....	......	.....	......	.....	......	.....	......
1913-14	11-12	40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......	1- 8	5	.....	......	1- 4	4	0- 9	2	5-10	19	2-13	10

1914-15	172-2	600	4-6	17	0-12	3	4-8	17	4-7	16	20-2	74	39-2	144	0-5	1	13-15	47	17-8	60	34-4	112	27-12	91	5-1	18
1915-16	151-12	552	2-4	9	9-7	34	12-7	46	10-0	37	3-14	14	5-7	20	7-7	28	12-12	45	30-0	107	28-6	102	20-3	74	9-9	36
1916-17	95-11	366	3-8	15	3-10	14	2-2	8	3-11	14	4-14	19	8-11	37	4-2	16	.....	.....	16-3	61	17-4	64	31-10	118	0	0
Average	121.24	448.17	5.26	22.40	5.65	20.80	10.06	36.20	20.25	74.00	17.96	68.00	19.79	78.80	6.56	25.83	7.55	26.00	9.98	35.57	16.61	57.80	17.84	63.00	4.18	15.20
Tree-Ripe grade—																										
1911-12	14-4	63	1-0	4	0	0	0	0	0-10	4	1-7	6	3-3	13	2-8	12	2-4	11	1-2	5	0-8	2	1-10	6	0	0
1912-13	23-2	110	0-12	3	0	0	0	0	0-10	3	0-3	1	3-0	14	18-9	89	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0-3	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	.....	.....	0	0	0-3	1	0	0	0	0
1914-15	26-7	113	0	0	0	0	0	0	0	0	0-3	1	7-10	37	0-7	2	5-8	24	5-15	25	3-11	12	2-1	8	1-0	4
1915-16	36-4	167	0-10	3	0-8	2	0-3	1	0-14	4	2-2	8	4-12	21	2-4	17	0-6	3	0-11	4	1-8	6	18-11	82	3-11	16
1916-17	25-14	111	0-10	3	0-4	1	0-3	1	0-6	2	0-3	1	1-14	10	0	0	.....	.....	6-9	25	4-0	16	9-8	39	2-5	13
Average	21.02	94.17	0.60	2.60	0.15	0.60	0.08	0.40	0.50	2.60	0.83	3.40	4.09	19.00	3.96	20.00	2.03	9.50	2.05	8.43	1.98	7.40	6.38	27.00	1.40	6.60
Cull grade—																										
1911-12	5-5	37	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4-4	28	0-4	2	0-11	4	0-2	3	0	0
1912-13	59-14	524	0-2	1	0-6	4	0-3	1	0-5	2	0-9	4	2-14	18	29-10	157	25-13	337	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0-2	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	.....	.....	0	0	0	0	0-2	1	0	0
1914-15	5-2	32	0-6	3	0	0	0	0	0	0	0-10	4	0	0	0-2	1	1-1	6	1-15	12	0	0	0-11	4	0-5	2
1915-16	6-11	39	0	0	0	0	0-7	2	0-3	1	0-7	3	0	0	0	0	0-9	4	0-6	2	0-6	3	2-11	15	1-10	9
1916-17	9-10	67	0-6	2	0	0	0	0	0	0	0	0	0	0	0-2	1	.....	.....	0-2	1	0-2	1	0-6	3	8-8	59
Average	14.46	116.67	0.22	1.50	0.09	1.00	0.16	0.75	0.13	0.75	0.41	2.75	0.72	4.50	5.98	31.80	7.92	93.75	0.38	2.43	0.24	1.60	0.80	5.20	2.09	14.00
Total crop—																										
1911-12	168-13	650	14-10	65	11-3	43	30-11	108	38-15	136	21-4	74	13-13	64	9-0	36	10-0	51	6-5	24	3-13	15	5-12	22	3-7	12
1912-13	229-14	1,215	3-7	14	3-10	14	0-12	3	45-12	176	41-14	170	40-15	174	67-11	327	25-13	337	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	12-1	42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1-8	5	.....	.....	1-4	4	0-12	3	5-12	20	2-13	10
1914-15	203-11	745	4-12	20	0-12	3	4-8	17	4-7	16	20-15	79	46-12	181	0-14	4	20-8	77	25-6	97	37-15	124	30-8	103	6-6	24
1915-16	194-11	758	2-14	12	9-15	36	13-1	49	11-1	42	6-7	25	10-3	41	9-11	45	13-11	52	31-1	113	30-4	111	41-9	171	14-14	61
1916-17	131-3	544	4-8	20	3-14	15	2-5	9	4-1	16	5-1	20	10-9	47	4-4	17	.....	.....	22-14	87	21-6	81	41-8	160	10-13	72
Average	**156.72**	**659.00**	**6.04**	**26.20**	**5.88**	**22.20**	**10.26**	**37.20**	**20.85**	**77.20**	**19.11**	**73.60**	**24.45**	**101.40**	**15.50**	**72.33**	**17.50**	**129.25**	**12.41**	**46.43**	**18.82**	**66.80**	**25.01**	**95.20**	**7.66**	**35.80**
Variable fruits—																										
1914-15	.....	71	.....	1	.....	0	.....	0	.....	2	.....	3	.....	7	.....	0	.....	3	.....	8	.....	14	.....	26	.....	7
1915-16	.....	117	.....	5	.....	5	.....	3	.....	2	.....	0	.....	6	.....	9	.....	22	.....	25	.....	7	.....	31	.....	2
1916-17	.....	128	.....	0	.....	3	.....	0	.....	2	.....	2	.....	8	.....	6	.....	.....	.....	27	.....	39	.....	41	.....	0
Average	.....	105.33	.....	2.00	.....	2.67	.....	1.00	.....	2.00.	.....	1.67	.....	7.00	.....	5.00	.....	8.33	.....	20.00	.....	20.00	.....	32.67	.....	3.00
Average seeds per fruit—																										
1911-12	.....	2.52	.....	1	.....	0	.....	0	.....	1	.....	0	.....	0	.....	3	.....	5	.....	9	.....	3	.....	1	.....	6
1912-13	.....	1.70	.....	2	.....	6	.....	3	.....	1	.....	0	.....	0	.....	0	.....	9	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	7.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....	.....	.....	4	.....	8	.....	8	.....	4
1914-15	.....	5.56	.....	2	.....	10	.....	7	.....	0	.....	3	.....	1	.....	4	.....	4	.....	7	.....	10	.....	4	.....	13
1915-16	.....	8.67	.....	10	.....	5	.....	5	.....	9	.....	6	.....	6	.....	5	.....	8	.....	14	.....	16	.....	10	.....	7
Average	.....	5.28	.....	3.44	.....	5.15	.....	4.15	.....	3.44	.....	2.64	.....	1.56	.....	3.55	.....	6.12	.....	9.44	.....	10.33	.....	5.78	.....	8.88

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
95. Dense-Unproductive strain:																										
Green grade—																										
1911-12	180-0	639	12-4	44	17-14	69	46-3	163	41-10	147	15-13	58	25-10	85	2-11	10	4-4	14	5-9	20	3-10	13	3-5	12	1-3	4
1912-13	84-11	326	1-2	4	0-14	3	1-2	5	19-5	71	30-9	116	19-3	73	12-8	54	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	19-7	68	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2-13	10	4-6	15	.....	.....	2-8	8	1-8	5	3-10	12	4-10	18
1914-15	211-2	747	7-8	28	2-14	11	3-13	16	4-5	17	27-7	102	34-0	122	2-4	9	46-10	157	11-15	43	15-8	54	46-10	158	8-4	30
1915-16	133-11	504	2-5	9	15-5	56	7-11	29	6-1	23	12-1	45	10-3	39	17-7	67	16-12	63	9-12	36	13-8	50	19-0	73	3-10	14
1916-17	59-13	223	5-8	23	0	0	0-8	2	2-7	11	2-10	10	3-1	12	1-14	7	.....	.....	10-8	33	6-14	25	26-7	100	0	0
Average	114.79	417.83	5.74	21.60	7.39	27.80	11.86	43.00	14.75	53.80	17.70	66.20	15.81	56.83	6.85	27.00	16.90	58.50	5.75	20.00	8.20	29.40	19.80	71.00	3.54	13.20
Tree-Ripe grade—																										
1911-12	11-12	56	0	0	0	0	0	0	0	0	0-6	2	2-0	9	2-0	12	4-2	18	1-10	8	1-1	4	0-9	3	0	0
1912-13	6-6	31	0	0	0	0	0	0	0-3	1	0-5	1	1-15	9	3-15	20	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	.....	.....	0	0	0	0	0	0	0	0
1914-15	57-12	247	0	0	0	0	0	0	0-10	3	0-10	3	3-12	18	8-11	43	22-15	94	8-10	37	1-8	6	6-10	25	4-6	18
1915-16	37-8	177	1-3	5	0-9	3	0-14	4	0-3	1	3-5	13	3-14	19	3-6	24	0-3	1	0	0	1-12	6	17-9	78	4-10	23
1916-17	12-6	49	0-11	4	0	0	0	0	0	0	0	0	0-3	1	1-2	4	.....	.....	3-10	11	1-10	7	5-2	22	0	0
Average	20.96	93.33	0.38	1.80	0.11	0.60	0.18	0.80	0.20	1.00	0.93	3.80	1.96	9.33	13.19	17.17	6.81	28.25	1.98	8.00	1.19	4.60	5.98	25.60	1.80	8.20
Cull grade—																										
1911-12	4-3	34	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3-4	27	0-4	2	0-3	1	0-6	3	0-2	1
1912-13	45-10	455	0-4	2	0	0	0-3	1	0-8	3	0-2	3	0-12	4	8-5	48	35-8	394	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0-2	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0-2	1	0	0	.....	.....	0	0	0	0	0	0	0	0
1914-15	7-3	46	0	0	0	0	0	0	0-6	3	0-2	1	1-11	6	0	0	2-8	17	0-12	5	0-9	5	0-12	6	0-7	3
1915-16	9-4	58	0-6	3	0-5	2	0-5	2	0	0	0-5	2	0-3	1	0	0	0	0	0	0	0-13	7	3-14	22	3-1	19
1916-17	8-14	66	0-15	6	0	0	0-2	1	0	0	0	0	0-3	2	0	0	.....	.....	0	0	0	0	0-7	3	7-3	54
Average	12.54	110.00	0.39	2.75	0.07	0.50	0.16	1.00	0.21	1.50	0.14	1.50	0.59	2.80	1.66	9.60	10.31	109.50	0.14	1.00	0.31	2.60	1.09	6.80	2.16	15.40
Total crop—																										
1911-12	195-15	729	12-4	44	17-14	69	46-3	163	41-10	147	16-3	60	27-10	94	4-11	22	11-10	59	7-7	30	4-14	18	4-4	18	1-5	5
1912-13	136-11	812	1-6	6	0-14	3	1-5	6	20-0	75	31-0	120	21-14	86	24-12	122	35-8	394	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	19-9	69	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2-15	11	4-6	15	.....	.....	2-8	8	1-8	5	3-10	12	4-10	18
1914-15	276-1	1,040	7-8	28	2-14	11	3-13	16	5-5	23	28-3	106	39-7	146	10-15	52	72-1	268	21-5	85	17-9	65	54-0	189	13-1	51

1915–16	180– 7	739	3–14	17	16– 3	61	8–14	35	6– 4	24	15–11	60	14– 4	59	20–13	91	16–15	64	9–12	36	16– 1	63	40– 7	173	11– 5	56
1916–17	81– 1	338	7– 2	33	0	0	0–10	3	2– 7	11	2–10	10	3– 7	15	3– 0	11	.....	.....	14– 2	44	8– 8	32	32– 0	125	7– 3	54
Average	**148.29**	**621.17**	**6.42**	**25.60**	**7.56**	**28.80**	**12.16**	**44.60**	**25.13**	**56.00**	**18.74**	**71.20**	**18.26**	**68.50**	**11.43**	**52.17**	**34.03**	**196.25**	**7.87**	**29.00**	**9.70**	**36.60**	**26.86**	**103.40**	**7.50**	**36.80**
Variable fruits—																										
1914–15	.....	128	.....	4	.....	0	.....	0	.....	1	.....	7	.....	1	.....	1	.....	27	.....	6	.....	10	.....	57	.....	14
1915–16	.....	148	.....	12	.....	4	.....	5	.....	6	.....	11	.....	16	.....	22	.....	23	.....	18	.....	3	.....	23	.....	5
1916–17	.....	67	.....	1	.....	0	.....	0	.....	1	.....	0	.....	2	.....	1	.....	.....	.....	20	.....	18	.....	24	.....	0
Average	.....	114.33	.....	5.67	.....	1.33	.....	1.67	.....	2.67	.....	6.00	.....	6.33	.....	8.00	.....	16.67	.....	14.67	.....	10.33	.....	34.67	.....	6.33
Average seeds per fruit—																										
1911–12	.....	2.05	.....	1	.....	0	.....	1	.....	0	.....	0	.....	1	.....	0	.....	8	.....	5	.....	1	.....	3	.....	2
1912–13	.....	1.44	.....	0	.....	1	.....	1	.....	3	.....	2	.....	0	.....	0	.....	7	.....	.....	.....	.....	.....	.....	.....	.....
1913–14	.....	4.83	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....	7	.....	.....	.....	6	.....	5	.....	0	.....	1
1914–15	.....	4.48	.....	2	.....	0	.....	3	.....	1	.....	1	.....	1	.....	3	.....	1	.....	3	.....	13	.....	9	.....	11
1915–16	.....	7.49	.....	8	.....	10	.....	7	.....	5	.....	4	.....	2	.....	0	.....	4	.....	27	.....	14	.....	9	.....	9
Average	.....	4.43	.....	3.71	.....	5.33	.....	3.57	.....	2.33	.....	1.82	.....	1.83	.....	1.20	.....	4.50	.....	7.29	.....	9.44	.....	6.89	.....	8.00
99. Small-Open strain: Green grade—																										
1911–12	106–14	395	8–14	34	8– 1	31	9– 4	35	14– 8	53	13– 8	49	14– 7	52	3–15	15	5– 7	20	11– 0	40	2– 4	8	8–14	32	6–12	26
1912–13	44– 6	183	0– 8	2	1– 6	6	1– 2	5	9– 0	36	9– 9	40	13– 7	54	8–15	38	0– 7	2	.....	.....	.....	.....	.....	.....	.....	.....
1913–14	3– 2	12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0– 4	1	0– 4	1	.....	.....	0– 9	2	0	0	1– 2	4	0–15	4
1914–15	155– 0	574	1– 7	6	1– 0	4	1–10	6	1– 4	5	6– 0	23	18– 6	75	2– 7	8	21– 2	74	19–15	72	28– 0	104	34– 4	125	19– 9	72
1915–16	109– 2	413	1– 4	5	2– 9	10	6–13	26	6– 0	24	0–14	3	1– 3	5	2– 5	10	9– 5	37	20– 4	75	25– 5	93	21– 2	80	12– 2	45
1916–17	90–14	376	5–12	23	4– 0	16	3– 0	10	6–10	27	5– 1	21	26– 9	117	1– 4	5	.....	.....	12– 6	48	20– 0	80	6– 0	28	0– 4	1
Average	84.90	325.50	3.56	14.00	3.40	13.40	4.36	16.40	7.48	29.00	7.00	27.20	12.38	50.67	3.19	12.83	9.07	33.25	9.16	33.86	15.11	57.00	14.28	53.80	7.93	29.60
Tree-Ripe grade—																										
1911–12	30– 3	137	1– 2	5	0	0	0	0	0	0	0–15	4	3– 3	15	1– 6	7	6– 6	33	7– 5	31	1–10	7	3– 9	14	4–11	21
1912–13	30– 6	157	0– 4	1	1– 6	7	0– 8	3	0– 7	2	1–11	9	2– 5	11	23– 8	122	0– 5	2	.....	.....	.....	.....	.....	.....	.....	.....
1913–14	0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	.....	.....	0	0	0	0	0	0	0	0
1914–15	81– 7	355	0	0	0	0	0	0	0– 3	1	0– 3	1	9–10	50	0	0	20–11	89	21–14	92	12–15	56	7–11	31	8– 4	35
1915–16	53–12	258	0– 7	2	2– 6	12	0– 7	2	1–10	8	6–14	27	7– 5	36	2– 3	17	3– 7	20	0–15	8	2–10	11	21–10	98	3–14	17
1916–17	47–10	219	0–10	4	0–10	4	0	0	0–10	3	0–14	5	3– 7	20	2– 7	10	.....	.....	6–13	27	7– 9	33	24– 0	110	0–10	3
Average	40.56	187.67	0.49	2.40	0.88	4.60	0.19	1.00	0.58	2.80	2.11	9.20	4.31	22.00	4.92	26.00	7.70	36.00	5.28	22.57	4.95	21.40	11.38	50.60	3.49	15.20
Cull grade—																										
1911–12	6–10	53	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4– 5	35	1– 6	11	0– 2	1	0– 8	4	0– 5	2
1912–13	89– 7	866	0–10	4	0– 4	3	0– 2	1	0– 1	2	0–10	9	0–14	7	24– 7	159	62– 7	681	.....	.....	.....	.....	.....	.....	.....	.....
1913–14	0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	.....	.....	0	0	0	0	0	0	0	0
1914–15	7– 5	46	0	0	0	0	0	0	0	0	0– 4	2	0– 2	1	0	0	0– 6	3	1– 1	7	1– 6	9	2–14	17	1– 4	7
1915–16	10– 6	64	0–12	5	0– 9	4	0–12	5	0	0	0– 2	1	0– 2	1	0– 3	2	0– 4	2	0– 4	2	2– 0	11	2– 9	15	2–13	16
1916–17	7– 3	55	0– 8	3	0	0	0– 8	3	0– 3	2	0– 5	2	0– 8	6	0	0	.....	.....	0–11	6	1– 8	11	1– 4	10	1–12	12
Average	20.16	180.67	0.49	3.00	0.20	1.75	0.34	2.25	0.06	1.00	0.48	3.50	0.32	3.00	4.93	32.10	16.84	180.25	0.48	3.71	1.00	6.40	1.44	9.20	1.23	7.40

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
99. Small-Open strain—Continued.																										
Total crop—																										
1911-12	143-11	585	10- 0	39	8- 1	31	9- 4	35	14- 8	53	14- 7	53	17-10	67	5- 5	22	16- 2	88	19-11	82	4- 0	16	12-15	50	11-12	49
1912-13	164- 3	1,206	1- 6	7	3- 0	16	1-12	9	9- 8	40	11-14	58	16-10	72	56-14	319	63- 3	685	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	3- 2	12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0- 4	1	0- 4	1	.....	.....	0- 9	2	0	0	1- 2	4	0-15	4
1914-15	243-12	975	1- 7	6	1- 0	4	1-10	6	1- 7	6	6- 7	26	28- 2	126	2- 7	8	42- 3	166	42-14	171	42- 5	169	44-13	173	29- 1	114
1915-16	173- 4	735	2- 7	12	5- 8	26	8- 0	33	7-10	32	7-14	31	8-10	42	4-11	29	13- 0	59	21- 7	85	29-15	115	45- 5	193	18-13	78
1916-17	145-11	650	6-14	30	4-10	20	3- 8	13	7- 7	32	6- 4	28	30- 8	143	3-11	15	.....	.....	19-14	81	29- 1	124	31- 4	148	2-10	16
Average	**145.61**	**693.83**	**4.42**	**18.80**	**4.44**	**19.40**	**4.83**	**19.20**	**8.10**	**32.60**	**9.38**	**39.20**	**16.96**	**75.17**	**12.21**	**65.67**	**33.62**	**249.50**	**14.92**	**60.14**	**21.06**	**84.80**	**27.08**	**113.60**	**12.64**	**52.20**
Variable fruits—																										
1914-15	.....	46	.....	1	.....	0	.....	0	.....	0	.....	1	.....	0	.....	0	.....	6	.....	5	.....	5	.....	16	.....	12
1915-16	.....	75	.....	2	.....	0	.....	3	.....	2	.....	1	.....	1	.....	1	.....	14	.....	23	.....	11	.....	13	.....	4
1916-17	.....	80	.....	0	.....	0	.....	0	.....	5	.....	2	.....	18	.....	1	.....	.....	.....	10	.....	32	.....	12	.....	0
Average	.....	67.00	.....	1.00	.....	0	.....	1.00	.....	2.33	.....	1.33	.....	6.33	.....	0.67	.....	6.67	.....	12.67	.....	16.00	.....	13.67	.....	5.33
Average seeds per fruit—																										
1911-12	.....	4.29	.....	5	.....	4	.....	0	.....	0	.....	10	.....	3	.....	3	.....	1	.....	5	.....	8	.....	8	.....	1
1912-13	.....	3.96	.....	3	.....	8	.....	3	.....	0	.....	0	.....	0	.....	4	.....	14	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	9.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....	8	.....	.....	.....	6	.....	0	.....	13	.....	9
1914-15	.....	5.26	.....	0	.....	3	.....	0	.....	0	.....	0	.....	1	.....	2	.....	4	.....	4	.....	9	.....	16	.....	13
1915-16	.....	9.77	.....	13	.....	7	.....	7	.....	5	.....	12	.....	7	.....	5	.....	10	.....	16	.....	12	.....	9	.....	13
Average	.....	6.38	.....	6.56	.....	6.63	.....	3.75	.....	1.25	.....	5.00	.....	3.08	.....	4.20	.....	7.73	.....	8.44	.....	9.63	.....	11.33	.....	9.89
102. Shade-Tree strain:																										
Green grade—																										
1911-12	199- 7	682	8-14	31	21-12	78	70- 0	239	45- 1	149	11- 5	43	17- 9	60	2-13	11	4- 9	16	7-10	25	0- 6	1	3- 9	11	5-15	18
1912-13	152- 4	593	5- 0	17	7- 0	24	4- 9	15	45-12	170	38- 5	154	36-10	149	15- 0	64	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	4- 4	13	.....	.....	.....	.....	.....	.....	.....	.....	0- 8	2	0	0	0	0	.....	.....	0- 6	1	0	0	2- 3	6	1- 3	4
1914-15	144- 9	503	2-14	10	0- 8	2	6-11	23	38- 2	135	39- 8	140	16- 2	58	0- 4	1	8- 6	28	5- 6	19	3- 2	10	13-14	42	9-12	35
1915-16	126- 8	450	14- 4	52	37- 7	132	15- 7	56	15-11	57	9-11	37	4- 4	15	8-10	27	8-15	31	3-13	14	4- 0	13	2- 1	8	2- 5	8
1916-17	47-10	176	1- 4	5	1- 0	4	2- 7	9	5- 9	21	7- 1	26	5- 2	20	6- 9	24	.....	.....	9-12	34	2-10	10	6- 4	23	0	0
Average	112.44	402.83	6.45	23.00	13.54	48.00	19.83	68.40	30.04	106.40	17.73	67.00	13.28	50.33	5.54	21.17	5.47	18.75	3.85	13.29	2.03	6.80	5.59	18.00	3.84	13.00

Tree-Ripe grade—																										
1911-12	12-11	54	0	0	0	0	0	0	0	0	0-11	3	1-15	9	1-8	8	1-6	6	3-14	15	0-8	2	2-10	10	0-3	1
1912-13	17-14	86	0	0	0	0	0	0	0-5	1	0-8	3	1-15	8	14-2	69	1-0	5	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0-5	1	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	0	0	0	0	0-5	1	0	0
1914-15	13-13	61	0	0	0	0	0	0	0-9	3	0-12	4	6-10	29	0	0	0-8	2	2-14	12	0-10	3	1-10	7	0-4	1
1915-16	26-10	106	0-4	1	3-1	12	3-2	14	2-4	10	8-0	26	8-10	38	0	0	0	0	0	0	0-15	3	0	0	0-6	2
1916-17	9-1	49	0-6	2	0	0	0-6	2	0	0	0-13	4	0-12	3	0-4	1	.....	.....	2-5	19	0-7	2	3-12	16	0	0
Average	13.40	59.50	0.13	0.60	0.61	2.40	0.70	3.20	0.63	2.80	1.79	6.67	3.31	14.50	2.65	13.00	0.72	3.25	1.29	6.57	0.50	2.00	1.66	6.80	0.16	0.80
Cull grade—																										
1911-12	2-11	17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1-7	9	0	0	0	0	0-11	5	0-9	3
1912-13	50-7	477	0-3	1	0-7	4	0	0	0-4	4	0-12	5	1-4	7	15-12	93	31-13	363	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0-13	4	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....	0	0	0	0	0-10	3	0-3	1
1914-15	2-4	11	0	0	0	0	0	0	0-3	1	0-7	2	0-4	1	0	0	0-8	2	0-2	1	0-5	2	0-4	1	0-3	1
1915-16	3-13	25	0-1	1	0-15	6	0-7	3	0-7	3	0-2	1	0-11	4	0-3	1	0-3	1	0	0	0	0	0	0	0-12	5
1916-17	1-13	12	0	0	0	0	0-5	2	0	0	0	0	0-4	2	0	0	.....	.....	0	0	0	0	0-6	3	0-14	5
Average	10.30	91.00	0.06	0.50	0.34	2.50	0.19	1.25	0.22	2.00	0.26	1.60	0.49	2.80	3.19	18.80	8.48	93.75	0.02	0.14	0.06	0.40	0.39	2.40	0.51	3.00
Total crop—																										
1911-12	214-13	753	8-14	31	21-12	78	70-0	239	45-1	149	12-0	46	19-8	69	4-5	19	7-6	31	11-8	40	0-14	3	6-14	26	6-11	22
1912-13	220-9	1,156	5-3	18	7-7	28	4-9	15	46-5	175	39-9	162	39-13	164	44-14	226	32-13	368	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	5-6	18	.....	.....	.....	.....	.....	.....	.....	.....	0-8	2	0	0	0	0	.....	.....	0-6	1	0	0	3-2	10	1-6	5
1914-15	160-10	575	2-14	10	0-8	2	6-11	23	38-14	139	40-11	146	23-0	88	0-4	1	9-6	32	8-6	32	4-1	15	15-12	50	10-3	37
1915-16	156-15	581	14-9	54	41-7	150	19-0	73	18-6	70	17-13	64	13-9	57	8-13	28	9-2	32	3-13	14	4-15	16	2-1	8	3-7	15
1916-17	58-8	237	1-10	7	1-0	4	3-2	13	5-9	21	7-14	30	6-2	25	6-13	25	.....	.....	12-1	53	3-1	12	10-6	42	0-14	5
Average	**136.14**	**553.33**	**6.63**	**24.00**	**14.43**	**52.40**	**20.68**	**72.60**	**30.84**	**110.80**	**19.74**	**75.00**	**17.00**	**67.17**	**10.84**	**49.83**	**14.67**	**115.75**	**5.16**	**20.00**	**2.59**	**9.20**	**7.64**	**27.20**	**4.51**	**16.80**
Variable fruits—																										
1914-15	.....	100	.....	0	.....	0	.....	2	.....	8	.....	11	.....	4	.....	0	.....	7	.....	14	.....	9	.....	29	.....	16
1915-16	.....	124	.....	40	.....	6	.....	8	.....	11	.....	17	.....	10	.....	5	.....	11	.....	8	.....	6	.....	1	.....	1
1916-17	.....	27	.....	0	.....	0	.....	0	.....	1	.....	3	.....	1	.....	4	.....	.....	.....	12	.....	3	.....	3	.....	0
Average	.....	83.67	.....	13.33	.....	2.00	.....	3.33	.....	6.67	.....	10.33	.....	5.00	.....	3.00	.....	6.00	.....	11.33	.....	6.00	.....	11.00	.....	5.67
Average seeds per fruit—																										
1911-12	.....	0.60	.....	1	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	3	.....	2	.....	1	.....	1
1912-13	.....	.47	.....	1	.....	0	.....	1	.....	1	.....	0	.....	0	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	.86	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	0	.....	0	.....	.....	.....	3	.....	0	.....	1	.....	0
1914-15	.....	1.04	.....	1	.....	0	.....	0	.....	0	.....	0	.....	1	.....	0	.....	1	.....	5	.....	0	.....	3	.....	1
1915-16	.....	1.55	.....	0	.....	3	.....	2	.....	2	.....	1	.....	1	.....	0	.....	0	.....	0	.....	1	.....	10	.....	3
Average	.....	0.98	.....	0.86	.....	1.14	.....	1.00	.....	0.80	.....	0.25	.....	0.45	.....	0.0	.....	0.22	.....	3.29	.....	0.83	.....	2.44	.....	1.20
104. Pear-Shape strain: Green grade—																										
1911-12	110-6	396	3-8	13	3-7	14	6-15	26	19-12	73	16-1	58	33-6	112	4-14	17	9-11	36	12-12	47	0	0	0	0	0	0
1912-13	33-7	135	0-9	2	0-4	1	1-6	5	9-8	38	5-11	24	9-11	38	6-6	27	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	3-13	13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	1-15	6	1-14	7

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
104. Pear-Shape strain—Continued.																										
Green grade—Con.																										
1914-15	61- 9	226	1- 8	6	3- 2	13	7- 2	28	3- 0	12	4- 7	16	9- 9	36	1-10	6	12-10	44	1- 0	4	3- 6	12	9- 9	32	4-10	17
1915-16	103-10	376	0- 3	1	2-15	11	10- 6	41	14- 1	48	0-12	3	2- 3	8	2- 5	8	8- 1	27	16- 7	60	12- 7	45	8- 1	31	25-13	93
1916-17	29-15	118	2- 8	10	2- 0	9	1-12	7	1- 0	4	2-11	11	3-10	15	1- 6	5	.....	......	5- 6	20	8-10	33	1- 0	4	0	0
Average	57.13	210.67	1.65	6.40	2.35	9.60	5.51	21.20	9.46	35.00	5.93	22.40	11.69	41.80	3.31	12.60	7.59	26.75	5.93	21.83	4.89	18.00	4.11	14.60	6.46	23.40
Tree-Ripe grade—																										
1911-12	74- 4	337	0- 4	2	0	0	0	0	0	0	0	0	15-11	60	5- 4	23	36- 7	176	12- 6	54	0-14	5	0- 9	2	2-13	15
1912-13	31-10	168	0	0	0	0	0	0	0- 6	2	0-10	4	11- 0	54	19- 1	105	0- 9	3	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0-15	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0- 3	1	0	0	0	0	0-12	3
1914-15	48- 0	224	0	0	0	0	0- 8	2	0	0	1- 7	7	1- 0	4	15- 5	81	14- 9	66	3-12	17	1-10	7	2- 8	9	7- 5	31
1915-16	65-13	329	4- 0	17	0-13	4	4- 4	18	2- 2	10	4- 2	15	26-13	149	1- 0	9	0- 9	3	1- 2	7	1- 0	4	3- 7	20	16- 9	73
1916-17	90- 7	461	2- 2	10	0-15	6	0	0	0- 5	2	0-15	6	20- 2	116	2- 8	10	.....	......	11- 6	45	7- 8	39	44- 4	225	0- 6	2
Average	51.84	253.83	1.28	5.80	0.22	2.00	0.95	4.00	0.56	2.80	1.43	6.40	14.93	76.60	8.63	45.60	13.03	62.00	4.80	20.67	2.20	11.00	10.15	51.20	5.56	24.80
Cull grade—																										
1911-12	6- 7	53	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5- 4	44	0-14	6	0- 3	2	0- 2	1	0	0
1912-13	40-12	530	0	0	0- 2	1	0	0	0- 6	3	0- 9	5	0- 4	3	0-14	6	38- 9	512	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	0	0
1914-15	8- 2	56	0- 3	2	0- 2	1	0- 8	3	0- 2	1	0- 2	1	0- 3	1	0- 6	5	1- 2	8	1- 1	8	0- 8	3	0-11	5	3- 2	18
1915-16	12-10	86	0- 4	1	0- 7	3	0-10	4	1- 5	9	0-11	3	0- 6	3	0-10	5	3- 6	30	0- 3	1	1- 0	6	1- 0	7	2-12	14
1916-17	13- 9	120	0- 8	3	0	0	0- 4	3	0	0	0	0	0- 9	6	0	0	.....	......	2-12	20	2-12	25	3-12	41	3- 0	22
Average	13.58	140.83	0.24	1.50	0.17	1.25	0.34	2.50	0.45	3.25	0.34	2.25	0.34	3.25	0.47	4.00	12.08	148.50	0.81	5.83	0.89	7.20	1.11	10.80	1.78	10.80
Total crop—																										
1911-12	191- 1	786	3-12	15	3- 7	14	6-15	26	19-12	73	16- 1	58	49- 1	172	10- 2	40	51- 6	256	26- 0	107	1- 1	7	0-11	3	2-13	15
1912-13	105-13	833	0- 9	2	0- 6	2	1- 6	5	10- 4	43	6-14	33	20-15	95	26- 5	138	39- 2	515	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	4-12	17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0- 3	1	0	0	1-15	6	2-10	10
1914-15	117-11	506	1-11	8	3- 4	14	8- 2	33	3- 2	13	6- 0	24	10-12	41	17- 5	92	28- 5	118	5-13	29	5- 8	22	12-12	46	15- 1	66
1915-16	182- 1	791	4- 7	19	4- 3	18	15- 4	63	17- 8	67	5- 9	21	29- 6	160	3-15	22	12- 0	60	17-12	68	14- 7	55	12- 8	58	45- 2	180
1916-17	133-15	699	5- 2	23	2-15	15	2- 0	10	1- 5	6	3-10	17	24- 5	137	3-14	15	.....	......	19- 8	85	18-14	97	49- 0	270	3- 6	24
Average	**122.55**	**605.33**	**3.11**	**13.40**	**2.84**	**12.60**	**6.74**	**27.40**	**10.39**	**40.40**	**7.63**	**30.60**	**26.89**	**121.00**	**12.31**	**61.20**	**32.70**	**237.25**	**11.54**	**48.33**	**7.98**	**36.20**	**15.38**	**76.60**	**13.80**	**59.00**

Variable fruits—																										
1914-15	.....	247	.....	6	.....	6	.....	19	.....	6	.....	5	.....	8	.....	56	.....	43	.....	18	.....	6	.....	28	.....	44
1915-16	.....	433	.....	15	.....	12	.....	34	.....	28	.....	6	.....	76	.....	3	.....	17	.....	25	.....	25	.....	29	.....	163
1916-17	.....	313	.....	22	.....	11	.....	5	.....	2	.....	7	.....	55	.....	8	.....	.....	.....	25	.....	45	.....	119	.....	14
Average	.....	331.00	.....	14.33	.....	9.67	.....	19.33	.....	12.00	.....	6.00	.....	46.33	.....	22.33	.....	20.67	.....	22.67	.....	25.33	.....	58.67	.....	73.67
Average seeds per fruit—																										
1911-12	.....	0.94	.....	1	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	11	.....	0	.....	4
1912-13	.....	1.61	.....	5	.....	7	.....	0	.....	0	.....	0	.....	1	.....	2	.....	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	3.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	0	.....	5	.....	4
1914-15	.....	2.76	.....	2	.....	3	.....	0	.....	0	.....	0	.....	2	.....	0	.....	5	.....	1	.....	5	.....	9	.....	5
1915-16	.....	4.75	.....	8	.....	5	.....	2	.....	4	.....	2	.....	4	.....	4	.....	11	.....	5	.....	4	.....	6	.....	3
Average	.....	2.95	.....	4.00	.....	4.25	.....	1.00	.....	1.33	.....	0.60	.....	1.82	.....	1.64	.....	4.90	.....	1.89	.....	5.57	.....	6.25	.....	3.78
109. Shade-Tree strain:																										
Green grade—																										
1911-12	100-10	361	(1)	.....	6- 3	20	5- 2	20	12- 6	48	22- 8	80	17- 3	62	9- 0	32	13- 3	47	11-13	41	1- 2	4	0	0	2- 2	7
1912-13	86-12	360	0-11	3	0-10	3	0	0	14- 8	51	21- 5	93	29- 6	117	20- 4	93	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	5- 6	18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0- 9	2	.....	.....	.....	.....	0- 8	2	1-12	5	2- 9	9
1914-15	121-11	438	5- 2	18	2- 6	9	9- 5	33	11-15	45	14- 0	55	5- 9	21	2- 6	9	8- 6	28	9- 6	33	30- 4	105	16-10	58	6- 6	24
1915-16	129-10	482	1-15	7	11- 5	41	16-14	62	16- 8	60	17-12	65	9-12	37	6- 6	25	17-11	64	15- 8	60	11- 6	43	2-11	11	1-14	7
1916-17	35- 4	142	3-13	16	0- 8	2	0	0	2- 0	8	2- 2	9	1- 0	6	2- 3	9	.....	.....	10- 6	40	6-12	27	6- 8	25	0	0
Average	79.89	300.17	2.89	11.00	4.20	15.00	6.26	23.00	11.46	42.40	15.54	60.40	12.58	48.60	6.79	28.33	9.81	34.75	9.41	34.80	7.14	25.86	5.51	19.80	2.59	9.40
Tree-Ripe grade—																										
1911-12	22- 8	94	(1)	.....	0	0	0	0	0	0	1- 2	4	0-15	4	0- 6	2	8- 1	36	6- 1	24	2-15	13	1-11	6	1- 5	5
1912-13	26- 1	132	0	0	0	0	0	0	0	0	0- 5	1	0- 9	3	23-11	121	1- 8	7	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 4	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	.....	.....	.....	.....	0	0	0- 4	1	0	0
1914-15	20-10	89	0- 3	1	0	0	0- 3	1	0- 8	3	0-11	4	0-14	4	4- 1	20	2-12	11	2- 0	9	2- 8	9	5-12	22	1- 2	5
1915-16	51- 2	229	1- 1	5	1- 1	5	0-12	4	2- 0	10	16- 3	61	21-10	100	1- 2	7	0- 2	1	0- 7	3	0- 7	3	6- 5	30	0	0
1916-17	7- 1	34	0- 6	2	0	0	0	0	0	0	0	0	0- 9	3	0	0	.....	.....	2- 0	8	1- 2	6	3- 0	15	0	0
Average	21.27	96.50	0.40	2.00	0.21	1.00	0.19	1.00	0.50	2.60	3.66	14.00	4.91	22.80	4.88	25.00	3.11	13.75	2.10	8.80	1.00	4.43	3.40	14.80	0.49	2.00
Cull grade—																										
1911-12	7- 1	43	(1)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3-11	25	0-11	4	0-11	4	0	0	2- 0	19
1912-13	34-14	273	0	0	0- 1	1	0- 3	2	0- 2	1	0-14	7	1- 6	10	22-12	127	9- 8	125	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	.....	.....	.....	.....	0	0	0	0	0	0
1914-15	3- 4	21	0	0	0	0	0- 6	2	0- 6	3	0- 8	4	0- 5	2	0	0	0-10	4	0- 8	3	0	0	0- 9	3	0	0
1915-16	4-14	31	0	0	0-10	5	0- 3	1	0- 5	2	0-12	3	1- 0	8	0- 8	3	0- 5	2	0	0	0	0	1- 3	7	0	0
1916-17	9-13	75	0-10	5	0	0	0	0	0	0	0- 1	1	0	0	0- 9	5	.....	.....	0- 1	1	0- 4	3	0- 4	2	8- 0	58
Average	9.98	73.83	0.15	1.25	0.17	1.50	0.19	1.25	0.20	1.50	0.55	3.75	0.67	5.00	3.97	22.50	3.53	39.00	0.25	1.60	0.13	1.00	0.40	2.40	2.00	13.60
Total crop—																										
1911-12	130- 3	498	(1)	.....	6- 3	20	5- 2	20	12- 6	48	23-10	84	18- 2	66	9- 6	34	24-15	108	18- 9	69	4-12	21	1-11	6	5- 7	22
1912-13	147-11	765	0-11	3	0-11	4	0- 3	2	14-10	52	22- 8	101	31- 5	130	66-11	341	11- 0	132	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	5-10	19	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0- 9	2	.....	.....	.....	.....	0- 8	2	2- 0	6	2- 9	9
1914-15	145- 9	548	5- 5	19	2- 6	9	9-14	36	12-13	51	15- 3	63	6-12	27	6- 7	29	11-12	43	11-14	45	32-12	114	22-15	83	7- 8	29

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[1] This tree was added to the plat in August, 1911.

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6-year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Nubmer.	Weight.	Number.	Weight.	Number.
109. Shade-Tree strain—Continued.																										
Total crop—Contd.																										
1915-16	185-10	742	3- 0	12	13- 0	51	17-13	67	18-13	72	34-11	129	32- 6	145	8- 0	35	18- 2	67	15-15	63	11-13	46	10- 3	48	1-14	7
1916-17	52- 2	251	4-13	23	0- 8	2	0	0	2- 0	8	2- 3	10	1- 9	9	2-12	14	.....	.....	12- 7	49	8- 2	36	9-12	42	8- 0	58
Average	111.14	470.50	3.45	14.25	4.55	17.20	6.60	25.00	12.13	46.20	19.64	77.40	18.03	75.40	15.64	75.83	16.45	87.50	11.76	45.20	8.28	31.29	9.31	37.00	5.08	25.00
Variable fruits—																										
1914-15	.....	148	.....	0	.....	2	.....	0	.....	2	.....	7	.....	0	.....	1	.....	14	.....	14	.....	52	.....	38	.....	18
1915-16	.....	99	.....	1	.....	1	.....	4	.....	3	.....	3	.....	12	.....	11	.....	25	.....	18	.....	8	.....	13	.....	0
1916-17	.....	23	.....	0	.....	0	.....	0	.....	0	.....	1	.....	1	.....	1	.....	.....	.....	9	.....	6	.....	5	.....	0
Average	.....	90.00	.....	0.33	.....	1.00	.....	1.33	.....	1.67	.....	3.67	.....	4.33	.....	4.33	.....	13.00	.....	13.67	.....	22.00	.....	18.67	.....	6.00
Average seeds per fruit—																										
1911-12	.....	0.67	(1)	.....	.....	0	.....	0	.....	0	.....	0	.....	0	.....	1	.....	0	.....	3	.....	2	.....	0	.....	1
1912-13	.....	.33	.....	1	.....	2	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	1.40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	0	.....	3	.....	0
1914-15	.....	1.67	.....	5	.....	0	.....	0	.....	0	.....	0	.....	1	.....	0	.....	1	.....	3	.....	4	.....	4	.....	4
1915-16	.....	3.56	.....	1	.....	3	.....	2	.....	8	.....	1	.....	1	.....	4	.....	4	.....	4	.....	8	.....	6	.....	3
Average	.....	1.83	.....	2.17	.....	1.29	.....	0.88	.....	2.67	.....	0.18	.....	0.55	.....	1.36	.....	1.40	.....	3.13	.....	3.71	.....	3.89	.....	2.17
112. Dense-Unproductive strain:																										
Green grade—																										
1911-12	131- 8	456	11- 7	38	9- 7	35	28- 6	97	33- 0	119	19- 8	67	15- 8	52	2-12	10	3-13	12	5- 5	18	0- 9	2	0-15	3	0-14	3
1912-13	67-11	258	0- 5	1	1-15	7	2- 2	8	9-10	34	17-12	69	26-15	104	9- 0	35	0	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	4- 2	14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1- 9	5	0-14	3	1-11	6
1914-15	152- 7	554	2-11	10	3-15	14	10- 1	36	17-11	69	41-11	155	24-14	97	0- 5	1	9- 5	31	4- 8	15	15-15	53	10- 5	35	11- 2	38
1915-16	95- 9	344	4- 0	15	16-13	61	19- 4	68	13- 5	47	8- 8	32	0-12	3	7-11	28	5-15	22	7- 1	25	4- 9	16	4-11	17	3- 0	10
1916-17	20- 3	71	1-14	7	1- 9	6	1- 2	4	0	0	0- 4	1	3-10	9	0-11	3	.....	.....	2- 6	9	4-11	17	4- 0	15	0	0
Average	78.58	282.83	4.06	14.20	6.74	24.60	12.19	42.60	14.73	53.80	17.54	64.80	14.34	53.00	4.09	15.40	4.77	16.25	3.85	13.40	5.46	18.60	4.16	14.60	3.34	11.40

Tree-Ripe grade—																										
1911-12	8- 2	36	0	0	0	0	0	0	0	0	0- 2	1	1- 9	7	0- 3	1	2-10	12	2- 0	8	0-15	4	0- 3	1	0- 8	2
1912-13	11-12	53	0	0	0	0	0	0	0- 3	1	0	0	0- 3	1	10-12	48	0-10	3	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0
1914-15	21- 8	95	0	0	0	0	0	0	0- 8	3	0-13	4	1-14	9	1- 3	5	9-12	43	1- 9	6	3-15	17	0-14	3	1- 0	5
1915-16	28- 3	130	0- 2	1	0-10	3	4-10	21	2- 5	11	6- 1	23	8- 3	40	2- 5	14	0	0	0- 2	1	0- 4	1	3- 3	13	0- 6	2
1916-17	3- 5	13	0	0	0	0	0	0	0	0	0	0	0- 3	1	0	0	.....	.....	1- 0	4	0- 4	1	1-14	7	0	0
Average	12.15	54.50	0.03	0.20	0.13	0.60	0.93	4.20	0.60	3.00	1.40	5.60	2.40	11.60	2.89	13.60	3.25	14.50	0.94	3.80	1.08	4.60	1.23	4.80	0.38	1.80
Cull grade—																										
1911-12	1- 7	13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1- 0	10	0- 1	1	0	0	0	0	0- 6	2
1912-13	27-12	305	0	0	0- 2	1	0- 6	2	0	0	0- 2	1	0-10	6	1- 0	8	25- 8	287	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	0- 0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0
1914-15	6- 3	39	0- 3	1	0	0	0	0	0- 6	2	0-11	4	0- 2	1	0	0	2- 1	12	1- 8	10	0- 2	1	0	0	1- 2	8
1915-16	5- 4	34	0- 2	1	0- 2	1	0- 6	3	1- 0	6	0- 2	1	0- 4	2	0- 6	2	0- 4	3	0	0	0	0	1-12	10	0-14	5
1916-17	1- 7	10	0	0	0	0	0	0	0	0	0	0	0- 1	1	0	0	.....	.....	0	0	0- 6	2	0	0	1- 0	7
Average	7.01	66.83	0.08	0.50	0.06	0.50	0.19	1.25	0.34	2.00	0.23	1.50	0.27	2.50	0.34	2.50	7.20	78.00	0.31	2.20	0.10	0.60	0.35	2.00	0.68	4.40
Total crop—																										
1911-12	141- 1	505	11- 7	38	9- 7	35	28- 6	97	33- 0	119	19-10	68	17- 1	59	2-15	11	7- 7	34	7- 6	27	1- 8	6	1- 2	4	1-12	7
1912-13	107- 3	616	0- 5	1	2- 1	8	2- 8	10	9-13	35	17-14	70	27-12	111	20-12	91	26- 2	290	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	4- 2	14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1- 9	5	0-14	3	1-11	6
1914-15	180- 2	688	2-14	11	3-15	14	10- 1	36	18- 9	74	43- 3	163	26-14	107	1- 8	6	21- 2	86	7- 9	31	20- 0	71	11- 3	38	13- 4	51
1915-16	129- 0	508	4- 4	17	17- 9	65	24- 4	92	16-10	64	14-11	56	9- 3	45	10- 6	44	6- 3	25	7- 3	26	4-13	17	9-10	40	4- 4	17
1916-17	24-15	94	1-14	7	1- 9	6	1- 2	4	0	0	0- 4	1	3-14	11	0-11	3	.....	.....	3- 6	13	5- 5	20	5-14	22	1- 0	7
Average	**97.74**	**404.17**	**4.15**	**14.80**	**6.91**	**25.60**	**13.26**	**47.80**	**15.60**	**58.40**	**19.13**	**71.60**	**16.95**	**66.60**	**7.25**	**31.00**	**15.22**	**108.75**	**5.10**	**19.40**	**6.64**	**23.80**	**5.74**	**21.40**	**4.39**	**17.60**
Variable fruits—																										
1914-15	.....	128	.....	0	.....	1	.....	0	.....	7	.....	15	.....	8	.....	2	.....	14	.....	11	.....	33	.....	23	.....	14
1915-16	.....	90	.....	11	.....	5	.....	9	.....	1	.....	6	.....	3	.....	18	.....	5	.....	15	.....	5	.....	8	.....	1
1916-17	.....	21	.....	1	.....	0	.....	0	.....	0	.....	1	.....	3	.....	0	.....	.....	.....	3	.....	11	.....	5	.....	0
Average	.....	80.67	.....	5.00	.....	2.00	.....	3.00	.....	2.67	.....	7.33	.....	4.67	.....	6.67	.....	6.33	.....	9.67	.....	16.33	.....	12.00	.....	5.00
Average seeds per fruit—																										
1911-12	.....	0.75	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	2	.....	1	.....	2	.....	4
1912-13	.....	.53	.....	3	.....	3	.....	0	.....	0	.....	0	.....	0	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	.....
1913-14	.....	1.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	3	.....	0
1914-15	.....	1.28	.....	0	.....	0	.....	0	.....	1	.....	0	.....	0	.....	0	.....	0	.....	1	.....	3	.....	1	.....	6
1915-16	.....	4.27	.....	5	.....	1	.....	2	.....	4	.....	3	.....	1	.....	3	.....	1	.....	8	.....	4	.....	7	.....	11
Average	.....	2.01	.....	2.57	.....	1.43	.....	0.86	.....	1.78	.....	0.90	.....	0.27	.....	1.00	.....	0.33	.....	2.86	.....	2.38	.....	3.88	.....	6.67

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[1] This tree was added to the plat in August, 1911.

TABLE VIII.—*Detailed statement of the annual performance of 24 representative lemon trees of the Eureka variety for the 6 year period from July, 1911, to June, 1917, inclusive*—Continued.

Rank in Table VI, strain, grade, and season.	Total.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
117. Dense-Unproductive strain:[1]																										
Green grade—																										
1912-13	19-3	80	....	....	....	....	....	....	....	....	....	....	6-13	25	12-6	55	0	0	....	....	....	....	....	....	....	....
1913-14	11-13	39	....	....	....	....	....	....	....	....	0-4	1	0-4	1	0	0	....	....	0	0	0	0	5-14	18	5-7	19
1914-15	43-10	150	4-10	17	1-12	7	4-12	16	2-5	9	6-4	21	1-4	4	0	0	0-5	1	0-14	3	2-10	9	8-12	29	10-2	34
1915-16	49-2	177	3-13	14	10-14	40	6-7	23	17-12	62	0	0	2-2	7	0-4	1	0-15	3	2-3	10	2-3	8	1-6	5	1-3	4
1916-17	13-12	54	3-2	12	0-8	2	0-4	1	0	0	1-4	5	3-6	15	0-4	1	....	....	1-14	7	0-8	2	2-10	9	0	0
Average	27.50	100.00	3.85	14.33	4.38	16.33	3.81	13.33	6.69	23.67	1.94	6.75	2.76	10.40	2.58	11.40	0.42	1.33	0.82	3.33	1.33	4.75	4.66	15.25	4.19	14.25
Tree-Ripe grade—																										
1912-13	17-7	87	....	....	....	....	....	....	....	....	....	....	0-12	4	14-14	75	1-13	8	....	....	....	....	....	....	....	....
1913-14	1-8	6	....	....	....	....	....	....	....	....	0	0	0	0	0	0	....	....	0-5	1	0-6	2	0-13	3	0	0
1914-15	3-10	15	0	0	0	0	0	0	0	0	0	0	0-7	2	0	0	1-6	6	0	0	1-9	6	0-4	1	0	0
1915-16	38-14	170	0-2	1	1-0	5	2-8	13	3-0	14	12-6	43	18-14	87	0-13	6	0	0	0	0	0	0	0	0	0-3	1
1916-17	11-12	51	0-11	4	0	0	0	0	0-7	2	0-3	1	3-5	16	0-4	1	....	....	1-0	3	1-14	7	3-10	15	0-6	2
Average	14.64	65.80	0.27	1.67	0.33	1.67	0.83	4.33	1.15	5.33	3.14	11.00	4.68	21.80	3.19	16.40	1.06	4.67	0.22	0.67	0.95	3.75	1.17	4.75	0.14	0.75
Cull grade—																										
1912-13	38-13	348	....	....	....	....	....	....	....	....	....	....	4-2	22	17-8	104	17-3	222	....	....	....	....	....	....	....	....
1913-14	0	0	....	....	....	....	....	....	....	....	0	0	0	0	0	0	....	....	0	0	0	0	0	0	0	0
1914-15	1-3	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0-9	3	0-4	1	0	0	0-6	2	0	0
1915-16	2-10	20	0	0	0-7	8	0-3	1	0-3	1	0-4	1	0-6	2	0	0	0-6	2	0	0	0	0	0-9	3	0-4	2
1916-17	2-13	23	0-5	2	0	0	0	0	0	0	0	0	0	0	0-2	1	....	....	0	0	0-4	3	0-8	3	1-10	14
Average	9.09	79.40	0.10	0.67	0.15	2.67	0.06	0.33	0.06	0.33	0.06	0.25	0.90	4.80	3.53	21.00	6.04	75.67	0.04	0.17	0.06	0.75	0.36	2.00	0.47	4.00
Total crop—																										
1912-13	75-7	515	....	....	....	....	....	....	....	....	....	....	11-11	51	44-12	234	19-0	230	....	....	....	....	....	....	....	....
1913-14	13-5	45	....	....	....	....	....	....	....	....	0-4	1	0-4	1	0	0	....	....	0-5	1	0-6	2	6-11	21	5-7	19
1914-15	48-7	171	4-10	17	1-12	7	4-12	16	2-5	9	6-4	21	1-11	6	0	0	2-4	10	1-2	4	4-3	15	9-6	32	10-2	34
1915-16	90-10	367	3-15	15	12-5	53	9-2	37	20-15	77	12-10	44	21-6	96	1-1	7	1-5	5	2-3	10	2-3	8	1-15	8	1-10	7
1916-17	28-5	128	4-2	18	0-8	2	0-4	1	0-7	2	1-7	6	6-11	31	0-10	3	....	....	2-14	10	2-10	12	6-12	27	2-0	16
Average	**51.23**	**245.20**	**4.22**	**16.67**	**4.85**	**20.67**	**4.71**	**18.00**	**7.90**	**29.33**	**5.14**	**18.00**	**8.34**	**37.00**	**9.29**	**48.80**	**7.52**	**81.67**	**1.08**	**4.17**	**2.34**	**9.25**	**6.19**	**22.00**	**4.80**	**19.00**

Variable fruits—																										
1914-15	......	41	......	0	......	0	......	0	......	1	......	3	......	0	......	0	......	2	......	4	......	3	......	11	......	17
1915-16	......	30	......	12	......	5	......	0	......	1	......	0	......	4	......	0	......	2	......	1	......	2	......	2	......	1
1916-17	......	18	......	0	......	0	......	0	......	0	......	0	......	5	......	1	......	......	......	4	......	3	......	5	......	0
Average	......	29.67	......	4.00	......	1.67	......	0	......	0.67	......	1.00	......	3.00	......	0.33	......	1.33	......	3.00	......	2.67	......	6.00	......	6.00
Average seeds per fruit—																										
1912-13[1]	......	0	......	......	......	......	......	......	......	......	......	......	......	0	......	0	......	0	......	......	......	......	......	......	......	......
1913-14	......	0.86	......	......	......	......	......	......	......	......	......	1	......	0	......	0	......	......	......	0	......	0	......	3	......	0
1914-15	......	1.89	......	2	......	2	......	4	......	5	......	0	......	0	......	0	......	0	......	2	......	0	......	5	......	1
1915-16	......	4.15	......	0	......	1	......	4	......	2	......	1	......	1	......	8	......	8	......	7	......	11	......	8	......	6
Average	......	2.92	......	0.67	......	1.25	......	4.25	......	2.50	......	0.75	......	0.67	......	8.50	......	3.20	......	3.67	......	2.75	......	5.14	......	4.00

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[1] This tree was added to the plat in December, 1912.

The notes that follow regarding some of the methods of recording and compiling the data presented in Table VIII may assist the reader to understand and interpret it.

The continuity of the records on this plat was badly disturbed by the severe freeze in the early part of January, 1913. It will be noted in Table VIII that no pickings were made from February to November, 1913. In summarizing the records it has been considered that all the trees were affected to practically the same degree, and the crops recorded during this experiment have been credited as the production for the 6-year period. This procedure necessarily results in a decreased average annual yield as an index of the performance of the individual trees. However, this is not a serious matter, inasmuch as these studies are based primarily upon the relative character and behavior of the various strains, and their differences are as apparent during periods of unfavorable conditions as at times when production is normal.

Spaces left blank in these records indicate that no fruit was picked at that time. The absence of fruit of any special grade or of seeds at any time when a picking was made is indicated by zero.

The fruits of the Cull grade were not recorded separately until February, 1912. Previous to that time they had been included with those of the Tree-Ripe grade, and it is not possible to separate them.

In endeavoring to make pickings every month, unavoidable delays were sometimes occasioned by unfavorable conditions of climate, by interfering periods of irrigation, or from other causes. In this way it sometimes happened that the interval between pickings was considerably prolonged beyond the 30-day schedule time. Because of the longer time required to secure the records at seasons when the crop was increasing in amount it was necessary to begin the picking a few days in advance of the corresponding date in the previous month. Unfavorable weather conditions during the winter season often delayed the progress of the work from a day to a week at a time so that during that period it was usually necessary to keep at the record work continuously in order to forestall unforseen delays and interruptions. The ideal way to obtain data such as these would be to determine the number of days required to make the records at the season when the crops were lightest, then to have a sufficient number of trained men available so that the work could be begun on the corresponding date each month and completed in the same minimum number of days, regardless of the weather or other unfavorable conditions. However, this ideal is impossible of attainment under practical conditions.

Table IX records the first and last dates of each period for picking lemons on the Eureka study plat. As already stated, no records were made from February to November, 1913, on account of the injury occasioned by the freeze in January of that year. In February, 1914, and again in February, 1917, unavoidable conditions delayed the work so that no pickings were made for about 45 days.

TABLE IX.—*Dates on which fruit was picked from the lemon trees of the Eureka variety in the investigational performance-record plat from July, 1911, to June, 1917, inclusive.*

Month.	First and last date of each picking period.					
	1911–12	1912–13	1913–14	1914–15	1915–16	1916–17
July	July 5 to 12	July 1 and 2		July 9 to 14	July 21 to 23	Aug. 1 and 2.
August	Aug. 1 to 7	Aug. 1 to 3		Aug. 5 and 6	Aug. 27 to 31	Sept. 4 and 5.
September	Aug. 28 to Sept. 5.	Aug. 26 to 27		Sept. 8 to 10	Sept. 23 to 27	Oct. 3 and 4.
October	Oct. 2 to 10	Oct. 1 to 9		Oct. 9 to 13	Oct. 25 to 28	Oct. 27 to 30.
November	Nov. 3 to 10	Nov. 1 to 6	Nov. 5 and 6	Nov. 7 to 17	Nov. 23 to 27	Nov. 28 and 29
December	Dec. 4 to 11	Dec. 2 to 6	Dec. 15	Dec. 14 to 21	Dec. 20 to 28	Jan. 2 and 5.
January	Jan. 3 to 6	Jan. 2 to 13	Jan. 23	Jan. 1 to 6	Jan. 26 to Feb. 1.	Jan. 31 and Feb. 1.
February	Feb. 1 to 7	Feb. 2 to 18		Feb. 12 to 19	Feb. 25 to Mar. 3.	
March	Mar. 2 to 15		Mar. 10 to 11	Mar. 8 to 12	Mar. 23 to 27	Mar. 16 to 20
April	Apr. 1 to 3		Apr. 4 to 7	Apr. 6 to 12	Apr. 25 to May 2.	Apr. 17 to 19.
May	May 3 to 6		May 20 to 22	May 14 to 19	May 25 to 31	May 26 to 29.
June	May 30 to June 1.		June 13 to 16	June 18 to 21	June 27 to 30	June 30 to July 2.

The excessive number of fruits of the Cull grade recorded in January and February, 1913, was largely the result of injury by the January freeze. All the small fruit on the trees at that time was badly frozen, so that there was nothing to be picked for several months afterward, and all the frozen fruit was recorded as of the Cull grade.

Variable fruits were first recorded in September, 1912. Because of the interruption to the records occasioned by the freeze of the following January and the subsequent period during which no fruit was picked from these trees, the data presented for the variable fruits are confined to the three years from July, 1914, to June, 1917, inclusive. In counting the variable fruits found on the different trees the typical fruit for the variety is made the standard, and all variations from it are recorded. This practice has been followed with all the trees, even those of the Pear-Shape strain.

In explanation of the relatively large number of variable fruits recorded from many of the trees, even of the Eureka strain, it should be said that several of the forms listed vary but slightly from the typical fruit of the variety. In fact, it is believed that some of these forms are continuous variations of fluctuations induced to some extent by certain climatic conditions, and they are characteristic to a greater or less degree of all lemon trees, so far as studied. Three such forms have been designated as collared, protruding blossom end, and ridged. On nearly all the trees under observation from 75 to 90 per cent of the fruits recorded as variable have been of these classes. The more marked variations which show a greater departure from the type of the different varieties, and those forms which have been proved to be true bud mutations usually appear more frequently and more abundantly in trees of some of the unproductive or otherwise undesirable strains than they do in trees of the standard strain of the variety.

The presence of variable fruits on all the trees and the fact that some trees produce many more such fruits than other trees emphasize the need of having reliable individual-tree performance records for use as a basis in selecting trees from which bud wood can be taken for commercial propagations. It is not sufficient to know that certain trees produce heavy crops, but data must be available to show the number and kind of variations on the trees, so that only those will be chosen which bear the most uniform and desirable fruit.

In Table X are presented the total number of the different variable forms which were recorded for three years on the trees listed in Table VIII. The typical fruits of the Pear-Shape strain produced on the trees listed in ranks 71 and 104 are recorded as bottle shaped, and other fruits on the same trees having a tendency toward that typical shape are classed as collared. These collared fruits are believed to be of a different character from the collared fruits commonly found on trees of other strains, but being like them in appearance they were listed in the same class. Propagations have been made to determine this point.

Wherever no record was made of any factor for one or more months it is thought that the most practicable method of computing the monthly averages in Table VIII is by dividing the monthly totals by the number of months represented in each total. For example, the averages for the production of Green-grade fruit by the tree in rank 1 in Table VIII during July, August, September, and October were computed by dividing the monthly totals by the factor 5, as there are records for five years during those months. In November, December, and January the records for six years are available. In February the pickings were missed in 1914 and 1917 and the average for that month is obtained by using the factor 4. In March records were secured during five years but the crops harvested in that month in 1914 and 1917 were in reality the yields for two months in each case, so the factor 7 has been used in determining the average for that month. It is recognized that this resulting average is not strictly accurate, but it is believed to represent more nearly the correct average for the period than any other figure that can be presented in this table. Because of the use of different factors, as just mentioned, the totals of the monthly averages are not equivalent to the average for the yearly totals. Other instances in this and other tables will be found where the decimal portions of averages of total records do not exactly correspond with the totals of the averages of the corresponding numbers. This is due to the small errors occasioned by the practice of retaining only two decimal places in average figures.

TABLE X.—*Number of variable fruits of different forms produced during the 3-year period from July, 1914, to June, 1917, inclusive, on the 24 individual lemon trees of the Eureka variety listed in Table VIII.*

[The several trees are designated by numbers denoting their rank (as shown in Table VIII), the strain to which each belongs being indicated by abbreviations, as follows: DP=Dense Productive, DU=Dense Unproductive, E=Eureka, PS=Pear Shape, SO=Small Open, ST=Shade Tree.]

Description of fruit variations.	Tree designations by rank and strain.											
	1, E.	9, E.	17, E.	22, SO.	26, E.	27, DP.	35, E.	43, E.	52, E.	60, E.	63, ST.	66, DP.
Collared	174	28	42	159	36	142	113	36	20	23	40	77
Protruding blossom end	195	102	55	189	121	193	59	83	69	142	159	131
Collared and protruding	63	14	7	111	26	81	38	17	6	23	33	35
Bottle shaped	1	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....
Raised section	6	2	2	25	1	2	2	2	1	5	4	2
Raised ridge	14	25	29	67	23	24	29	13	18	15	31	14
Ridged	62	48	27	95	43	58	66	18	18	18	25	47
Ridged and collared	5	.....	3	6	4	8	3	2	3	3	12	9
Ridged and protruding	20	24	18	20	19	37	27	8	3	14	26	25
Ridged, collared, and protruding	3	5	3	5	2	9	8	1	2	7	12	2
Sunken section	1	.....	.....	12	.....	1	1	.....	.....	.....	1	1
Creased	27	5	4	43	6	12	12	12	3	6	14	12
White section	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....
Raised white section	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....
Sunken white section	1	.....	.....	5	.....	.....	.....	.....	.....	.....	.....	.....
Striped	.....	.....	1	6	.....	.....	.....	.....	.....	.....	2	.....
Ribbed	.....	.....	.....	24	.....	.....	.....	1	.....	1	1	.....
Corrugated	.....	.....	.....	12	.....	.....	.....	1	.....	.....	4	.....
Abnormal shape	.....	.....	.....	1	.....	3	.....	.....	.....	.....	.....	2
Miscellaneous variations	6	2	.....	16	2	2	2	4	2	1	8	3
3-year totals	578	255	191	798	283	572	361	198	145	258	372	360
Percentage of total crop	11.4	6.0	4.7	20.5	8.9	13.3	9.5	6.7	4.4	9.8	13.8	11.2

Description of fruit variations.	Tree designations by rank and strain.											
	71, PS.	72, E.	81, SO.	88, E.	93, ST.	95, DU.	99, SO.	102, ST.	104, PS.	109, ST.	112, DU.	117, DU.
Collared	868	120	20	44	54	34	41	76	613	103	105	40
Protruding blossom end	14	98	48	85	103	123	82	50	6	5	16	12
Collared and protruding	22	47	5	6	37	41	5	14	15	11	10	2
Bottle shaped	466	.....	.....	.....	.....	.....	.....	1	286	.....	1	.....
Raised section	.....	2	1	.....	3	2	1	1	.....	.....	1	1
Raised ridge	5	8	13	27	25	16	16	2	4	9	9	2
Ridged	4	75	40	28	27	28	23	41	1	79	27	13
Ridged and collared	1	5	6	1	3	3	3	17	.....	19	27	5
Ridged and protruding	.....	18	16	7	34	43	14	10	.....	21	11	3
Ridged, collared, and protruding	1	7	3	1	10	33	2	4	1	7	4	4
Sunken section	1	.....	.....	.....	.....	1	.....	.....	.....	1	.....	.....
Creased	17	9	10	4	6	6	11	16	6	6	12	7
White section	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Raised white section	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....
Sunken white section	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....
Striped	176	.....	.....	.....	.....	.....	.....	.....	61	.....	.....	.....
Ribbed	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....
Corrugated	.....	.....	.....	.....	10	3	.....	.....	.....	.....	1	.....
Abnormal shape	.....	.....	.....	.....	.....	1	1	6	.....	.....	.....	.....
Miscellaneous variations	1	2	3	5	3	8	2	13	.....	8	18	.....
3-year totals	1576	391	165	208	316	343	201	251	993	270	242	89
Percentage of total crop	50.4	15.8	6.4	6.9	15.4	16.2	8.5	18.0	49.7	17.5	18.8	13.4

A study of the number of seeds produced by the individual trees was made by cutting one typical fruit of each of the Green grade, the Tree-Ripe grade, and the Cull grade from each tree at each picking up to June, 1916, at which time these records were discontinued. In case one or more grades of fruit was not represented at any picking no substitution was made in determining the seed content. Normally, each figure recorded in Table VIII under this heading is the average of three fruits, but in some instances it has been secured from one or two fruits. The total averages shown for each month, those for each season, and those for the five years were obtained by factoring the total number of seeds and the number of fruits examined for that purpose during the period indicated rather than by averaging the monthly averages.

The average number of seeds per fruit indicated by this method varies considerably from the true average of all the fruits produced. There is a considerable variation in seed content on the trees of many of the strains between the fruit produced during different months. Fruit production is much heavier in certain months than during other months, while in the system of averaging here used, which was the only practicable one under the circumstances, equal weight is given to the seed data for each month.

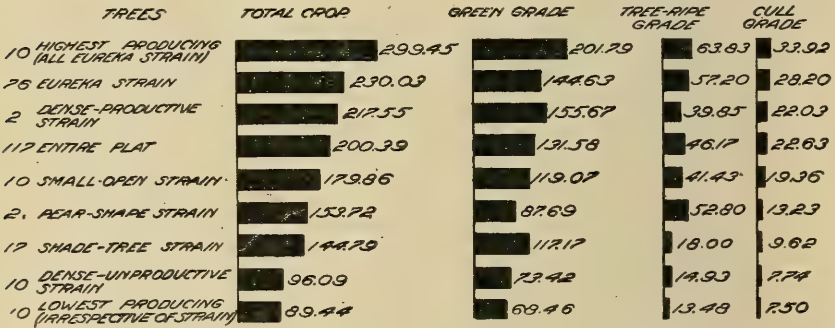

Fig. 10.—Diagram showing the average annual total crops and the amounts of fruit of the different commercial grades produced by the trees of the several strains of Eureka lemons occurring in the investigational performance-record plat during the 6-year period from July, 1911, to June, 1917, inclusive. The strains are ranked according to the weight of their average total crops.

Table XI shows the average annual crops of the individual Eureka lemon trees in the investigational performance-record plat, arranged in groups of strains and of select trees within some of the strains. The strains are listed in the order of their rank by total crops by weight, and the production of fruit of the different grades is also shown. These averages are shown graphically in figure 10. Several of the strains are represented by different numbers of individuals, so no exact comparisons can be drawn between them. However, as in nearly every case the trees within each strain have shown a considerable degree of uniformity with respect to their various characteristics, the data shown in this and the following tables are thought to be fairly indicative of the relative values of the different strains represented.

Table XI shows the trees of the Eureka strain to be more productive than those of any other in the list, with an average annual production of 230 pounds for the 6-year period. Of the 76 Eureka trees in the plat, 35 were above this average and 41 below it, as shown in Table VI. The limits of the average individual-tree production within the strain were 338.24 pounds and 165.86 pounds, being 108.21 pounds (or 47.1 per cent) above the mean and 64.17 pounds (or 27.9 per cent) below it, respectively. In each of the other strains represented by 10 or more individuals, the individual-tree variations are also considerably greater above the mean than below it.

TABLE XI.—*Average annual crop of the individual lemon trees of several of the important strains found in the investigational performance-record plat of the Eureka variety, ranked according to the weight of their average total crops, for the 6-year period from July, 1911, to June, 1917, inclusive.*

Number of trees.	Description of trees.	Average annual production per tree.							
		Total crop.		Green grade.		Tree-Ripe grade.		Cull grade.	
		Pounds.	Number.	Pounds.	Number.	Pounds.	Number.	Pounds.	Number.
10	Highest producing (all Eureka strain)	299.45	1,341.83	201.71	754.00	63.83	292.65	33.92	295.18
76	Eureka strain	230.03	1,051.88	144.63	541.58	57.20	263.29	28.20	247.01
2	Dense-Productive strain	217.55	980.83	155.67	576.83	39.85	183.75	22.03	220.25
117	Entire plat	200.39	902.91	131.58	490.16	46.17	212.07	22.63	200.68
10	Small-Open strain	179.86	808.88	119.07	445.68	41.43	188.70	19.36	174.50
2	Pear-Shape strain	153.72	721.25	87.69	328.58	52.80	264.50	13.23	128.17
17	Shade-Tree strain	144.79	597.33	117.17	426.93	18.00	79.47	9.62	90.93
10	Dense-Unproductive strain	96.09	405.00	73.42	266.30	14.93	66.82	7.74	71.88
10	Lowest producing (irrespective of strain)	89.44	379.42	68.46	250.25	13.48	60.83	7.50	68.33

Table XII shows the percentage of fruit of the three commercial picking grades produced by the trees of the various Eureka strains, together with the average number and percentage of variable fruits recorded in each strain. The strains are here listed in the order of their rank by percentages of fruit of the Green grade produced per tree. The Shade-Tree, Dense-Unproductive, and Dense-Productive strains rank considerably above the others under this classification. However, it should be remembered that while in general fruit of the Green grade is superior to that of the Tree-Ripe grade, the fruit of the three strains just mentioned is much inferior in texture, thickness of skin, and other characteristics to that of the Eureka strain; hence, the superiority which would appear to be indicated by a study of this table alone is entirely lost when consideration is given to the character of the fruit itself.

While the trees of the Small-Open strain are shown to have produced a slightly higher percentage of Green-grade fruit than the trees of the Eureka strain, the actual production of the trees of the Small-Open strain is so much less than that of those of the Eureka strain that the inferiority of that strain is very apparent. The decreased percentage of Cull-grade fruit produced by the trees of the Shade-Tree, Dense-Unproductive, and Dense-Productive strains is probably due to the closer habit of growth of those trees, which lessens the number of fruits knocked from the trees or marred and scratched by the movement of the branches by the wind. The more compact trees also protect their fruits from sunburn to a greater extent than those of a more open character.

As shown by the last two columns in Table XII and graphically in figure 11, the fruit produced by the trees of the Eureka strain is more uniform in character than that borne on the trees of the other strains. The 7.68 per cent of variable fruit produced by the trees of the Eureka strain seems large, but the number is much less than was produced by the trees of the other strains, and if the minor forms and fluctuating variations were deducted this percentage would be very greatly reduced.

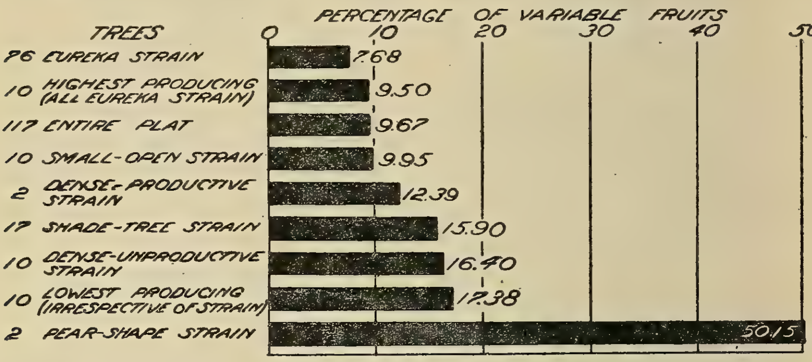

FIG. 11.—Diagram showing the percentages of variable fruits occurring on the trees of the different strains of Eureka lemons in the investigational performance-record plat during the 3-year period from July, 1914, to June, 1917, inclusive. The proportions are based on the number of fruits produced.

TABLE XII.—*Production of fruit of the three different grades and of variable fruits picked from the lemon trees of the several strains of the Eureka variety in the investigational performance-record plat during the 6-year period from July, 1911, to June, 1917, inclusive.*

[The data for variable fruits cover the 3-year period from July, 1914, to June, 1917, inclusive. The strains are ranked according to their proportion (by weight) of fruit of the Green grade.]

Number of trees.	Description of trees.	Percentage of weight of total crop.			Variable fruits.	
		Green grade.	Tree-Ripe grade.	Cull grade.	Average yearly number per tree.	Per cent.
17	Shade-Tree strain	80.92	12.43	6.65	99.84	15.90
10	Lowest producing (irrespective of strain)	76.54	15.07	8.39	69.00	17.38
10	Dense-Unproductive strain	76.40	15.54	8.06	68.77	16.40
2	Dense-Productive strain	71.56	18.32	10.13	155.33	12.39
10	Highest producing (all Eureka strain)	67.36	21.32	11.33	148.53	9.50
10	Small-Open strain	66.20	23.03	10.77	93.77	9.95
117	Entire plat	65.66	23.04	11.29	95.68	9.67
76	Eureka strain	62.87	24.87	12.26	88.16	7.68
2	Pear-Shape strain	57.04	34.35	8.61	428.17	50.15

TABLE XIII.—*Average yields and percentages of total yield of fruit of the Green and Tree-Ripe grades picked each month from the lemon trees of the various strains of the Eureka variety in the investigational performance-record plat during the 3-year period from July, 1914, to June, 1917, inclusive.*

[The strains are listed in the order of their total-production rank for six years, as shown in Table X.]

Description of trees.	Number of trees.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Season.
PRODUCTION (IN POUNDS) AVERAGE.														
Green grade:														
Highest producing (all Eureka strain)	10	8.47	6.82	13.09	13.90	17.43	32.01	10.01	37.20	41.55	47.76	35.89	8.13	272.26
Eureka strain	76	5.64	4.67	8.14	9.78	9.08	17.97	5.21	20.19	25.30	35.40	30.67	8.05	180.11
Dense-Productive strain	2	8.18	5.38	12.95	10.36	15.99	22.91	10.13	31.59	37.05	42.63	27.15	6.80	231.10
Entire plat	117	5.71	5.87	9.09	10.89	10.59	16.24	4.99	17.27	20.83	28.57	25.35	7.21	162.60
Small-Open strain	10	5.75	4.45	7.18	8.00	9.28	14.90	4.80	17.78	21.43	26.17	26.58	7.48	153.79
Pear-Shape strain	2	3.74	7.65	13.28	12.48	12.79	16.36	3.02	7.54	5.99	7.57	6.65	6.51	103.58
Shade-Tree strain	17	6.67	11.26	13.65	18.69	18.54	13.90	4.99	9.93	9.16	12.16	11.19	4.67	134.81
Dense-Unproductive strain	10	4.49	6.98	8.84	8.82	8.33	6.96	2.84	6.10	5.77	8.35	11.10	5.13	83.69
Lowest producing (irrespective of strain)	10	3.95	7.44	9.59	10.63	10.13	7.24	2.52	5.49	5.50	7.74	7.29	4.03	81.56
Tree-Ripe grade:														
Highest producing (all Eureka strain)	10	1.56	1.28	1.07	1.65	3.75	19.91	4.99	10.19	8.89	13.34	23.91	4.50	95.05
Eureka strain	76	1.66	1.14	.90	1.61	4.04	13.72	3.59	9.24	6.78	10.23	23.48	5.56	81.94
Dense-Productive strain	2	.99	.59	.54	.72	4.95	12.88	2.67	7.48	7.42	9.66	14.98	3.04	65.91
Entire plat	117	1.36	.94	.81	1.37	3.96	11.96	2.96	7.26	5.41	7.96	18.07	4.36	66.43
Small-Open strain	10	2.05	.96	.72	1.07	3.83	10.53	2.75	6.85	5.89	7.90	16.33	4.81	63.70
Pear-Shape strain	2	1.51	.65	1.26	1.56	7.57	32.33	3.80	3.98	2.68	3.09	12.58	4.65	75.67
Shade-Tree strain	17	.28	.47	.49	.82	3.56	6.66	1.28	2.21	1.64	2.12	4.43	.88	24.85
Dense-Unproductive strain	10	.28	.34	.64	.91	3.26	4.85	1.13	1.94	1.07	1.24	3.70	.84	20.19
Lowest producing (irrespective of strain)	10	.23	.29	.64	.90	3.30	5.07	.86	1.35	.81	1.08	2.43	.36	17.31
PERCENTAGE OF WEIGHT OF TOTAL CROP.[1]														
Green grade:														
Highest producing (all Eureka strain)	10	3.1	2.5	4.8	5.1	6.4	11.8	3.7	13.7	15.3	17.5	13.2	3.0	21.8
Eureka strain	76	3.1	2.6	4.5	5.4	5.0	10.0	2.9	11.2	14.1	19.7	17.0	4.5	27.2
Dense-Productive strain	2	3.5	2.3	5.6	4.5	6.9	9.9	4.4	13.7	16.0	18.4	11.8	2.9	20.5
Entire plat	117	3.5	3.6	5.6	6.7	6.5	10.0	3.1	10.6	12.8	17.6	15.6	4.4	27.1
Small-Open strain	10	3.7	2.9	4.7	5.2	6.0	9.7	3.1	11.6	13.9	17.0	17.3	4.9	28.8
Pear-Shape strain	2	3.6	7.4	12.8	12.0	12.3	15.8	2.9	7.3	5.8	7.3	6.4	6.3	23.7
Shade-Tree strain	17	4.9	8.4	10.1	13.9	13.8	10.3	3.6	7.4	6.8	9.0	8.3	3.5	25.1
Dense-Unproductive strain	10	5.4	8.3	10.6	10.5	9.9	8.3	3.4	7.3	6.9	10.0	13.3	6.1	33.1
Lowest producing (irrespective of strain)	10	4.8	9.1	11.8	13.0	12.4	8.9	3.1	6.7	6.7	9.5	8.9	4.9	27.7
Tree-Ripe grade:														
Highest producing (all Eureka strain)	10	1.6	1.3	1.1	1.7	4.0	21.0	5.3	10.7	9.4	14.0	25.2	4.7	32.8
Eureka strain	76	2.0	1.4	1.1	2.0	4.9	16.7	4.4	11.3	8.3	12.5	28.6	6.8	38.8
Dense-Productive strain	2	1.5	.9	.8	1.1	7.5	19.5	4.0	11.4	11.3	14.7	22.7	4.6	29.7
Entire plat	117	2.0	1.4	1.2	2.1	6.0	18.0	4.5	10.9	8.2	12.0	27.2	6.6	37.2
Small-Open strain	10	3.2	1.5	1.1	1.7	6.0	16.5	4.3	10.7	9.2	12.4	25.6	7.6	37.9
Pear-Shape strain	2	2.0	.8	1.7	2.1	10.0	42.7	5.0	5.3	3.5	4.1	16.6	6.1	25.5
Shade-Tree strain	17	1.1	1.9	2.0	3.3	14.3	26.8	5.2	8.9	6.6	8.5	17.9	3.5	24.4
Dense-Unproductive strain	10	1.4	1.7	3.2	4.5	16.2	24.0	5.6	9.6	5.3	6.1	18.3	4.2	25.6
Lowest producing (irrespective of strain)	10	1.3	1.7	3.7	5.2	19.1	29.3	5.0	7.8	4.7	6.3	14.0	2.1	19.1

[1] The season percentage is calculated on the production for the four months, May to August, inclusive.

In Table XIII and in figures 12, 13, and 14 are shown some of the recorded differences in season of production of fruits of the Green and Tree-Ripe grades by the Eureka lemon trees of the various strains. On account of the interruption to regular picking which resulted from the freeze in January, 1913, only the three years from July, 1914, to June, 1917, inclusive, have been considered in this study. During this period pickings were made every month except in February, 1917, when interfering rains made it impossible to do the work at the scheduled time. Inasmuch as it would be unfair to consider the fruit picked in March, 1917, as all produced during one month, it was decided that for the purpose of this comparison of seasonable production the crops picked at that time should be arbitrarily halved and credited to February and March equally.

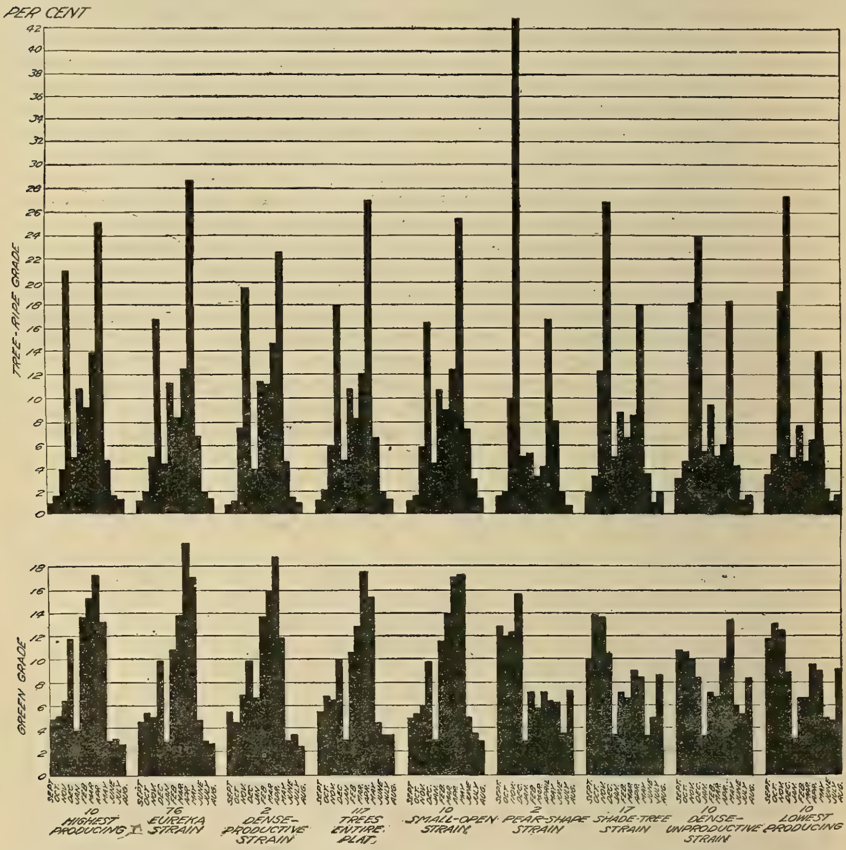

FIG. 12.—Diagram showing the percentages of the total yields of Green-grade fruits and of Tree-Ripe fruits, by weight, produced each month by the trees of the various strains of Eureka lemons in the investigational performance-record plat during the 3-year period from July, 1914, to June, 1917, inclusive. The strains are arranged from left to right in the order of their rank for total production, as shown in Table X.

The first part of Table XIII shows the average individual-tree production of fruit of the Green and Tree-Ripe grades for each month, expressed in pounds. The comparative behavior of each strain in this respect is best studied by expressing the monthly yields in percentages of the annual crop, and these data are given in the second part of the table, and are shown graphically in figures 12 and 13.

In choosing between lemon trees which were alike in all other respects, that one would be considered the most desirable which produced the largest quantity of fruit of the Green grade during May, June, July, and August. The summer heat causes a considerably increased consumption of lemons, resulting normally in a higher price being paid for them, especially in the late summer when the supply is greatly reduced. Hence it will be understood that, other things being equal, the most valuable variety or strain for the grower will be that one which produces the larger proportion of its fruit in the late spring and summer. Such fruit can be shipped immediately after it has been cured, and under normal conditions it will bring satisfactory prices.

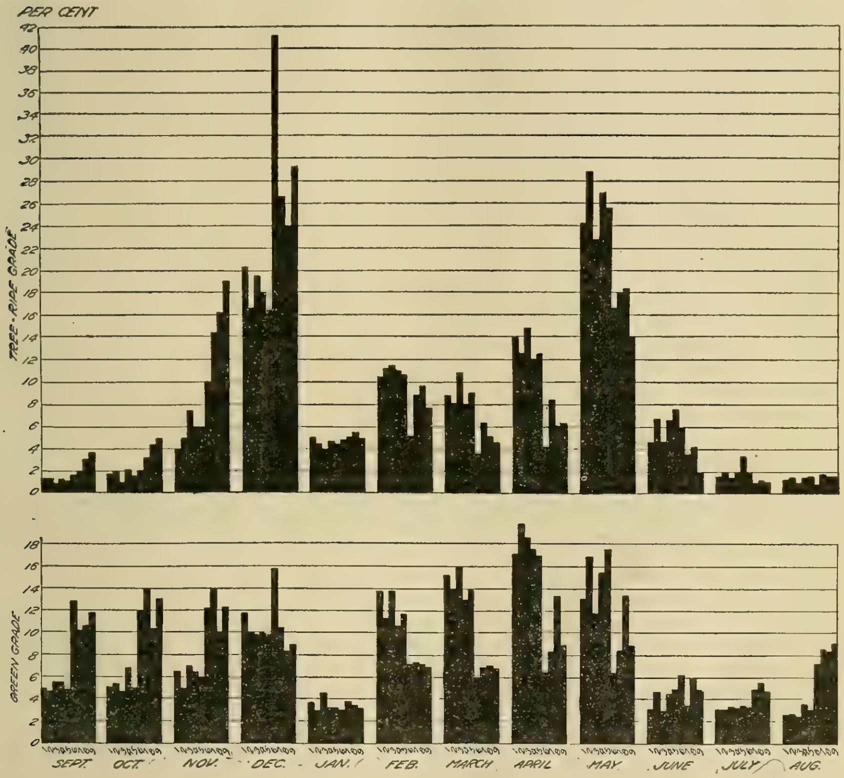

FIG. 13.—Percentages of the total yields of fruits of the Green and the Tree-Ripe grades, by weight, produced each month by the trees of the various strains of Eureka lemons in the investigational performance-record plat during the 3-year period from July, 1914, to June, 1917, inclusive. The data here presented are the same as those presented in figure 12, being here rearranged to show more clearly the variations between the different strains each month. The strains are listed from left to right in the same order as in figure 12. Arrangement of strains: *1*, Ten highest producing trees; *2*, 76 trees of the Eureka strain; *3*, 2 trees of the Dense-Productive strain; *4*, 117 trees, entire plat; *5*, 10 trees of the Small-Open strain; *6*, 2 trees of the Pear-Shape strain; *7*, 17 trees of the Shade-Tree strain; *8*, 10 trees of the Dense-Unproductive strain; *9*, 10 lowest producing trees.

Fruit of the Green grade is normally picked only when it has reached a certain diameter. In practice this size sometimes varies at different seasons or on account of changed market requirements, and in securing the investigational performance records the same standard of picking was followed each month as that used in the regular commercial picking. Table XIV shows the ring size used for Green-grade fruit at each picking from July, 1911, to June, 1917, inclusive. Fortunately for this study of seasonal variation, it will be noted that there was no change in ring size during the last two years of the study period. Fruit of the Tree-Ripe grade is sometimes picked as soon as it appears, and sometimes it is not picked until it reaches a certain size, which is usually smaller than the standard being used for fruit of the Green grade. The practice varies in different orchards, and in any one orchard it is usually influenced by climatic and market conditions. On this account it is believed that a consideration of the fruit of the Green grade alone will give the truest index of the production habit of the various strains but the data for the fruit of the Tree-Ripe grade are included as a matter of interest.

TABLE XIV.—*Diameter of rings used in picking fruits of the Green grade from the lemon trees of the Eureka variety in the investigational performance-record plat during the 5-year period from July, 1912, to June, 1917, inclusive.*

Month.	Diameter of picking ring for Green-grade fruit (inches).						Month.	Diameter of picking ring for Green-grade fruit (inches).					
	1911–12	1912–13	1913–14	1914–15	1915–16	1916–17		1911–12	1912–13	1913–14	1914–15	1915–16	1916–17
July	$2\frac{9}{32}$	$2\frac{10}{32}$	.....	$2\frac{8}{32}$	$2\frac{9}{32}$	$2\frac{9}{32}$	January	$2\frac{9}{32}$	$2\frac{8}{32}$	$2\frac{10}{32}$	$2\frac{11}{32}$	$2\frac{9}{32}$	$2\frac{9}{32}$
August	$2\frac{9}{32}$	$2\frac{11}{32}$	.....	$2\frac{8}{32}$	$2\frac{9}{32}$	$2\frac{9}{32}$	February	$2\frac{9}{32}$	$2\frac{8}{32}$	.....	$2\frac{11}{32}$	$2\frac{9}{32}$	.....
September	$2\frac{9}{32}$	$2\frac{11}{32}$	.....	$2\frac{8}{32}$	$2\frac{9}{32}$	$2\frac{9}{32}$	March	$2\frac{9}{32}$	.....	$2\frac{10}{32}$	$2\frac{11}{32}$	$2\frac{9}{32}$	$2\frac{9}{32}$
October	$2\frac{9}{32}$	$2\frac{8}{32}$	.....	$2\frac{8}{32}$	$2\frac{9}{32}$	$2\frac{9}{32}$	April	$2\frac{9}{32}$	.....	$2\frac{8}{32}$	$2\frac{9}{32}$	$2\frac{9}{32}$	$2\frac{9}{32}$
November	$2\frac{9}{32}$	$2\frac{8}{32}$	$2\frac{10}{32}$	$2\frac{8}{32}$	$2\frac{9}{32}$	$2\frac{9}{32}$	May	$2\frac{9}{32}$	.....	$2\frac{8}{32}$	$2\frac{9}{32}$	$2\frac{9}{32}$	$2\frac{9}{32}$
December	$2\frac{9}{32}$	$2\frac{8}{32}$	$2\frac{10}{32}$	$2\frac{8}{32}$	$2\frac{9}{32}$	$2\frac{9}{32}$	June	$2\frac{9}{32}$	.....	$2\frac{8}{32}$	$2\frac{8}{32}$	$2\frac{9}{32}$	$2\frac{9}{32}$

In figure 12 the graphs representing the monthly production of fruit of the Green and Tree-Ripe grades are arranged by strains from left to right, according to their rank for average total production as shown by Table XI. To bring out more closely the variations in production each month between the trees of the different strains the data were rearranged as shown in figure 13. Each graph represents the proportions of fruit produced during a month by the trees of the various strains, which are presented in each month in the same order from left to right as in figure 12.

The low production in January of fruits of both the Green and Tree-Ripe grades by the trees of all the strains is quite marked, and it is probable that if all conditions had been normal the records would indicate a gradual upward curve at that time instead of the break that is shown. Table IX shows that in 1914 and 1916 the time between the November and December pickings was longer than usual, which would tend to increase the yield recorded for December. In those same two seasons the time between the December and January pickings was less than the normal period, resulting in a small recorded crop in January. Table XIV shows that a $2\frac{8}{32}$-inch ring was used in picking the fruit in December, 1914, and for several months previous, but in January, 1915, a change was made to a $2\frac{11}{32}$-inch ring. This in itself would decrease the picking for that month more than half what it would normally be if a ring of the same size as in the preceding month had been used. The variations in the intervals between the picking period in succeeding months and the changes in the size of the ring used tend to make the data of monthly production within the strains somewhat variable, but these variations do not affect the comparative studies between the various strains. It was the custom in the orchard where this plat was located to "clean up" all fruit of the Tree-Ripe grade on the trees in December and May, and the same practice was followed on the study plat, as is shown by the data for those months.

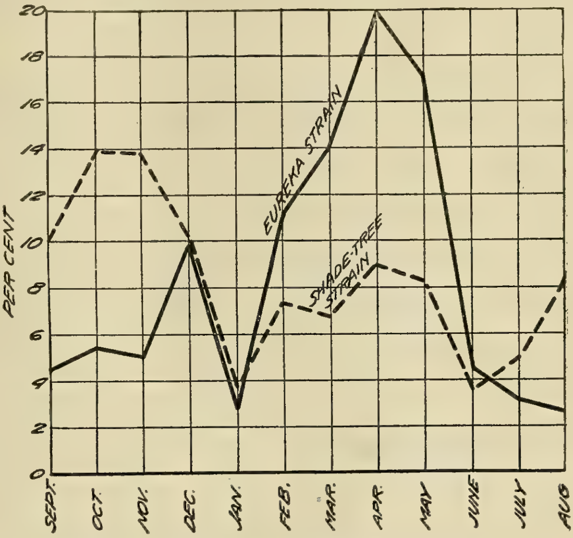

FIG. 14.—Diagram showing the percentages of the total annual crop of fruits of the Green grade produced each month by the trees of the Eureka and Shade-Tree strains of lemons in the investigational performance-record plat during the 3-year period from July, 1914, to June, 1917, inclusive.

It will be seen that there is considerable variation between the trees of some of the different strains in the period of their heaviest production. The trees of the Eureka, Dense-Productive, and Small-Open strains bear the largest proportions of their Green-grade fruit from February to May, inclusive, while the trees of the Pear-Shape, Shade-Tree, and Dense-Unproductive strains have their Green-grade fruit more evenly distributed throughout the year, with their maximum production from August to December, inclusive. If the fruit produced by the trees of the latter group of strains was desirable in texture and quality, their increase in production in August and September would tend to increase their value. As a matter of fact, this fruit is not only undesirable but the total production of the trees of these strains is so low as to make them expensive boarders for the grower.

This difference in time of production between the trees of two of the most important strains is very clearly shown in figure 14. This diagram indicates the relative percentage of the total yield of fruit of the Green grade that was produced each month by the trees of the Eureka and Shade-Tree strains, showing the large proportion of fruit borne by the trees of the Eureka strain from February to May, inclusive. During that period the trees of the Shade-Tree strain were yielding a relatively small proportion of their crop, the time of their heaviest production being from September to December, inclusive.

Additional data regarding the season of production is given in Table XV, which shows the production from the entire study plat at each picking during the 3-year period from July, 1914, to June, 1917, inclusive. This is the record of the number of field boxes of fruit produced each month, including the culls. Stated in this concise form, the normal variations in yield from month to month are clearly shown. A study of the second half of the table shows that there are variations in the season of production in succeeding years. These differences are probably due partly to varying climatic conditions in the different years, partly to unavoidable changes in the intervals between the pickings, partly to changes in the size of the ring used for picking the fruit of the Green grade, and partly to variations in the plan for picking the fruit of the Tree-Ripe grade.

TABLE XV.—*Fruit yields of the lemon trees of the Eureka variety in the investigational performance-record plat for each month during the 3-year period from July, 1914, to June, 1917, inclusive.*

[The yields are expressed in terms of the number of field boxes of fruit, including the culls.]

Month.	Total production (field boxes).				Monthly percentage.			
	1914–15	1915–16	1916–17	3-year total.	1914–15	1915–16	1916–17	3-year average.
July	18	25	14	57	2.40	3.43	2.93	2.91
August	5½	39	9	53½	0.73	5.35	1.88	2.73
September	16½	50½	10	77	2.20	6.93	2.09	3.93
October	19½	56½	19½	95½	2.60	7.76	4.08	4.88
November	43½	44¼	26½	114¼	5.79	6.07	5.55	5.84
December	92	69	53½	214½	12.25	9.47	11.20	10.96
January	13¾	32	18	63¾	1.83	4.39	3.77	3.26
February	112	50½	....	[a] 200¾	14.91	6.93	....	[a] 10.26
March	95	84	76½	217¼	12.65	11.53	16.02	11.10
April	147	97¾	123½	368¼	19.57	13.42	25.86	18.81
May	126½	143	109	378½	16.84	19.63	22.83	19.34
June	62	37	18	117	8.25	5.08	3.77	5.98
Total	751¼	728½	477½	1,957¼	....	....	....	....
Heaviest	April.	May.	April.	May.	....	....	....	....
Lightest	August.	July.	August.	August.	....	....	....	....

[a] February is credited with half of the production for March in 1917.

In order to show in a more striking manner the variations in fruit production by trees of the different strains, Table XVI has been prepared. This presents the calculated yields per acre of fruit of the

Green and Tree-Ripe grades from the trees of the various strains, on the basis of their production for the 3-year period from July, 1914, to June, 1917, inclusive, as shown in Table XIII. This indicates an average total commercial crop of 224 packed boxes per acre by the trees of the Eureka strain, and a yield of only 89 boxes per acre by the trees of the Dense-Unproductive strain. The 10 highest producing trees in the plat bore at the rate of 314 boxes per acre, while the 10 lowest producing trees would have borne only 84½ boxes on the acre basis. The average of the 10 highest producing trees was 60 per cent more than the average of the entire plat, and the average of the 10 lowest producing trees was only 34 per cent of the average of the plat as a whole, or 27 per cent of the amount produced by the 10 highest producing trees.

Table XVI.—*Annual yields and calculated production per acre of fruit of the Green and Tree-Ripe grades picked from the lemon trees of the various strains of the Eureka variety in the investigational performance-record plat for the 3-year period from July, 1914, to June, 1917, inclusive.*

Number of trees.	Description of trees.	Average annual production, 3-year period.					
		Production per tree (pounds).		Calculated production per acre (packed boxes).			Percentage of average of plat.
		Green grade.	Tree-Ripe grade.	Green grade.	Tree-Ripe grade.	Total.	
10	Highest producing (all Eureka strain)	272.26	95.05	232.93	81.32	314.25	160.36
76	Eureka strain	180.11	81.99	154.09	70.10	224.19	114.41
2	Dense-Productive strain	231.10	65.91	197.72	56.39	254.11	129.67
117	Entire plat	162.62	66.43	139.13	56.83	195.96	....
10	Small-Open strain	153.79	63.70	131.58	54.50	186.08	94.96
2	Pear-Shape strain	103.58	75.67	88.62	64.74	153.36	78.26
17	Shade-Tree strain	134.81	24.85	115.34	21.26	136.60	69.71
10	Dense-Unproductive strain	83.69	20.19	71.60	17.27	88.87	45.35
10	Lowest producing (irrespective of strain)	1.56	17.31	69.78	14.81	84.59	43.17

Inasmuch as it is the practice in picking lemons to go over the trees at regular intervals, picking each time all fruit that is above a specified diameter, it is interesting to determine what differences there may be in the average weight of the fruits produced by the trees of the different strains. Because of the definite rules governing the time of picking and the size of the fruit picked, whatever differences are found between any of the strains are probably due to variations in (1) the rapidity of growth of the fruit, (2) the physical composition of the fruit, or (3) the shape of the fruit. The rapidity of growth of the fruit is influenced by the vegetative character of the trees and by the quantity of fruit produced. Thick-skinned fruits are lighter than thin-skinned ones of the same diameter. Short, rounded fruits are usually lighter than fruits of the same cross diameter which are longer, unless the increased length is largely made up of thickened peel

Table XVII gives the average weight per fruit of lemons of the Green and Tree-Ripe grades produced by the trees of the various strains of the Eureka variety during the 6-year period. The data for the two grades combined is shown graphically in figure 15. Many of the fruits of the Tree-Ripe grade are picked before they reach the size at which the Green-grade fruits are picked; hence, their average weight is less than that of the Green-grade fruits. Throughout the progress of these studies the fruits of the Pear-Shape strain have been recognized as decidedly slow growing, especially in view of the light production of the trees of that strain. The trees of the Dense-Unproductive and the Shade-Tree strains are not only low producers, but are also very vigorous growing, and their fruits are shown to be above the average of the other strains in weight, as would be expected.

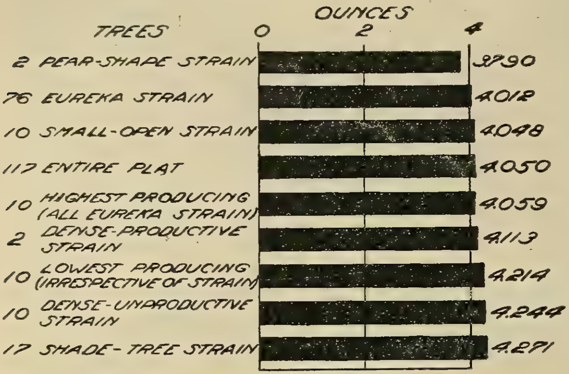

FIG. 15.—Diagram showing the average weight per fruit of the Green and Tree-Ripe grades from the trees of the various strains of Eureka lemons occurring in the investigational performance-record plat for the 6-year period from July, 1911, to June, 1917, inclusive.

TABLE XVII.—*Average weight per fruit for lemons of the Green and Tree-Ripe grades produced by the trees of the various strains of the Eureka variety in the investigational performance-record plat during the 6-year period from July, 1911, to June, 1917, inclusive.*

Number of trees.	Description of trees.	Average weight per fruit (ounces).		
		Green grade.	Tree-Ripe grade.	Both grades.
2	Pear-Shape strain	4.270	3.194	3.790
76	Eureka strain	4.273	3.476	4.012
10	Small-Open strain	4.275	3.513	4.048
117	Entire plat	4.295	3.483	4.050
10	Highest producing (all Eureka strain)	4.280	3.490	4.059
2	Dense-Productive strain	4.318	3.470	4.113
10	Lowest producing (irrespective of strain)	4.377	3.546	4.214
10	Dense-Unproductive strain	4.411	3.575	4.244
17	Shade-Tree strain	4.391	3.624	4.271

Figure 16 illustrates graphically the variations in the average seed content of the fruits from the lemon trees of the different strains of the Eureka variety in the investigational plat. It is shown that the fruits of the Eureka strain contain on the average 7.1 seeds per fruit, which is more than was found in the fruits of any other strain. The fruits from the undesirable Shade-Tree and Dense-Unproductive strains are more nearly seedless than any of the others, containing 1.84 and 2.26 seeds per fruit, respectively.

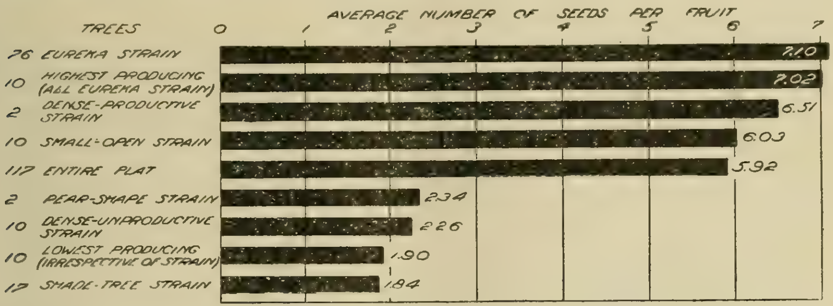

FIG. 16.—Diagram showing the average number of seeds per fruit on trees of the various strains of Eureka lemons in the investigational performance-record plat, during the 5-year period from July, 1911, to June, 1916, inclusive.

In conducting the studies of the seed content of the fruits it was very noticeable that there was a considerable variation in different months of the year. In order to show this seasonal variation, Table XVIII has been prepared, presenting the average number of seeds found in fruits of the various strains during each month. This table shows a fairly uniform regularity of variation during the different months for the several strains listed, the time of low seed content coming in October, November, and December, with a rapid increase from that time till April, May, and June. Figure 17 shows this variation graphically for the four strains that were most frequent in the performance-record plat. The other strains and groups shown in Table XVIII conform so closely with the curves shown in figure 17 that it was impracticable to represent all of them clearly in this diagram. A comparison of figures 16 and 17

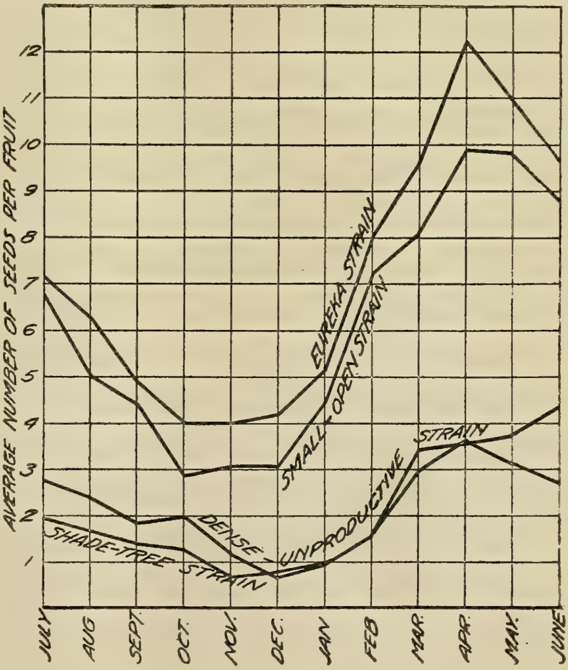

FIG. 17.—Diagram showing the average number of seeds per fruit found each month on trees of some of the most important strains of the Eureka lemon in the investigational performance-record plat, during the 5-year period from July, 1911, to June, 1916, inclusive.

shows that with the trees of the Eureka, Small-Open, and Dense-Productive strains the period of highest seed content corresponds in general with the time of the heaviest production of fruit.

TABLE XVIII.—*Average number of seeds per fruit picked from lemon trees of the various strains of the Eureka variety in the investigational performance-record plat during each month of the 5-year period from July, 1911, to June, 1916, inclusive.*

Number of trees.	Description of trees.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	For the period.
76	Eureka strain	7.13	6.27	4.83	4.00	3.99	4.18	5.13	8.06	9.62	12.23	10.92	9.67	7.10
10	Highest producing (all Eureka strain)	6.87	6.36	5.20	3.50	3.54	4.46	6.04	8.93	9.29	11.85	10.63	8.46	7.02
2	Dense-Productive strain	5.25	6.69	6.59	3.00	2.22	3.69	4.33	7.50	8.42	10.52	11.80	9.20	6.51
10	Small-Open strain	6.75	5.00	4.39	2.86	3.08	3.07	4.49	7.22	8.07	9.90	9.81	8.80	6.03
117	Entire plat	6.18	5.32	4.16	3.33	3.14	3.29	4.15	6.64	8.15	10.29	9.11	8.30	5.92
2	Pear-Shape strain	3.00	3.60	1.13	1.60	.57	1.18	1.21	3.05	2.25	4.06	3.95	3.72	2.34
10	Dense-Unproductive strain	2.75	2.38	1.82	1.97	1.17	.68	.95	1.58	3.46	3.57	3.78	4.38	2.26
10	Lowest producing (irrespective of strain)	2.38	1.92	1.52	2.01	.94	.53	.94	1.26	2.66	2.41	3.41	3.65	1.90
17	Shade-Tree strain	1.93	1.67	1.40	1.28	.69	.78	.99	1.57	3.00	3.65	3.16	2.76	1.84

COMPARATIVE VALUE OF THE STRAINS.

The individual-tree performance-record studies of the Eureka lemon strains, and observations of typical trees of these strains in many orchards in different citrus districts have led to certain conclusions as to the comparative value of the different strains for commercial lemon production in California under existing cultural and marketing conditions.

In the Eureka variety only the Eureka, or Productive, strain has given satisfactory production from all standpoints. Its tendency to produce fruits throughout all seasons of the year is a valuable one. This characteristic of continual bearing has been the main reason for the planting of the Eureka variety by citrus growers in many districts.

The fruits of the Eureka strain are of desirable shape for making a satisfactory commercial package. The juice has a high percentage of acidity and is of superior quality. The fruits, after curing, develop a smooth texture of rind, have a light yellowish or strawlike color, giving them a waxlike appearance, and remain solid and firm when handled in the market.

The Variegated strain is of some value in a very limited way, particularly for ornamental purposes. The striking appearance of the striped leaves and fruits has led many persons living in the citrus districts of California to grow one or more of the Variegated trees in their home grounds. The fruits, while of little commercial value, are of fair quality for home use.

The other strains of the Eureka variety studied in these investigations are of little or no commercial value. Some of them, such as the Shade-Tree, the Pear-Shape, and the Sporting strains are actually very detrimental to the reputation of the California lemon industry, from the fact that the fruits from the trees of these strains are of inferior quality and when placed on the market are likely to be the cause of serious disappointment to the consumers. The Eureka strain is the only strain in this variety which is of commercial value.

THE UNINTENTIONAL PROPAGATION OF UNDESIRABLE STRAINS.

The originators and early propagators of lemon varieties in California have usually used the fruit characteristics as a measure of the comparative value of the parent trees for propagation. Later, the men who secured commercial bud wood from orchards of the established varieties lost sight of the importance of the fruits in the selection of parent trees as sources of bud wood. In most cases they secured bud wood from the trees where it was easiest to get it—that is, from vigorous-growing trees of the vegetative strains. These strains are usually the least productive and the least desirable. Other propagators assumed that the size of the tree was correlated with production; therefore they secured their bud wood from the largest trees. In other cases nurserymen assumed that they could grow the best nursery stock—that is, the largest nursery trees, in a given time from sucker bud wood secured from the largest parent trees. The result of these various practices has been the unintentional propagation of poor fruiting strains. It is believed that the most frequent and important cause of the propaga-

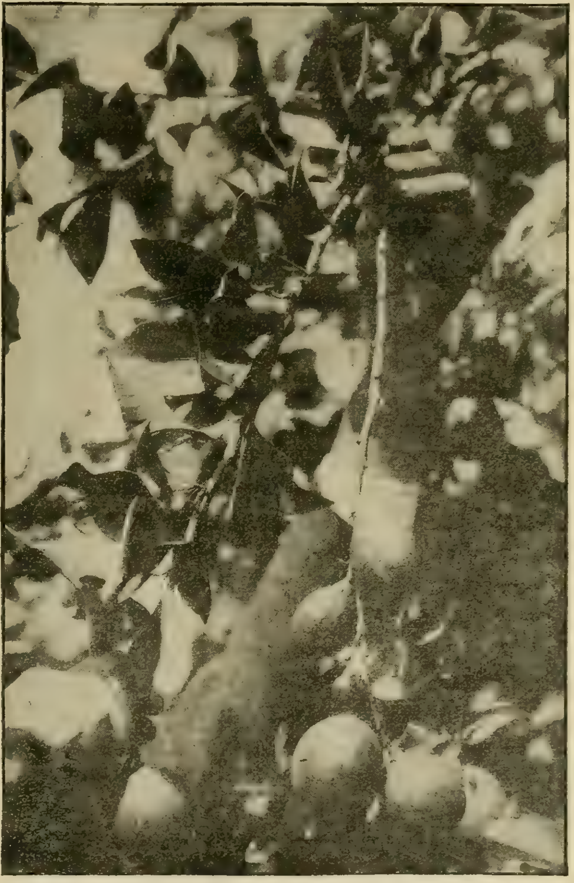

FIG. 18.—Fruit-bearing bud wood on a lemon tree of the Eureka strain, with typical fruits attached. The leaves have been removed from one bud stick in order to show the method of preparing the bud sticks for use.

tion of the undesirable strains has been the natural tendency of the bud cutters to secure bud wood from the trees producing the most suckers. In other words, they cut their bud wood from the trees where they could most easily and quickly secure the largest supplies.

The method of using fruit-bearing bud wood for the propagation of the citrus varieties, as shown in figure 18, has been evolved in the course of these investigations and has largely eliminated the danger of the unintentional propagation of the vegetative strains of the Eureka lemon. The use of fruit-bearing bud wood naturally results in bud cutters securing most of their bud wood from the most heavily fruited trees, because more fruit wood is available on such trees than on trees of the poor fruiting strains. When performance records are used as a basis for parent-tree selection and only that bud wood used for propagation which bears typical fruits, the danger of propagating the undesirable strains is largely eliminated.

THE ISOLATION OF STRAINS THROUGH BUD SELECTION.

The orchards of the Eureka lemon variety in California are made up of trees of many diverse strains which have originated from bud variations. The description and characteristics of some of the important strains have been presented herewith. It is obvious from these data and observations of the behavior of the trees of the different strains that some of them are not worthy of propagation, because of low and inferior production. Other strains mature their fruit during poor marketing seasons when the prices for lemons are usually low. The trees of some of the strains produce fruits low in acidity, of undesirable shapes for packing, of coarse ugly texture, with little or no juice, or with some other undesirable characteristics. It has been proved that a mixture of strains in orchards is very undesirable and is likely to make the maintenance of such orchards unprofitable.

After determining the relative value of the different strains for commercial production in California, the next step in these investigations was the attempt to isolate each of the important strains through bud selection. This study was made by propagating from typical trees of each strain, selecting the bud wood on the basis of tree-performance records and intimate tree knowledge. Only fruit-bearing bud wood was used for this pupose, with typical fruits of the strain attached to each bud stick.

The first trees grown from these propagations are now 4 years old from planting. Individual-tree performance records are being secured from some of these progenies. While the performance-record data obtained in the course of this work are incomplete as yet, there is sufficient evidence in hand to warrant the statement that each of the important lemon strains has been isolated through bud selection. This means that the strain characteristics in the progenies of the typical parent trees have been uniformly transmitted. Variations in some of the individual trees in these progenies, similar in degree to those of the parent trees, have been found. However, no mixture of strains has been discovered so far in the progenies. Therefore, it can be safely stated at this time that it is practicable to isolate the different strains through bud selection based upon individual-tree performance records and intimate tree knowledge.

TOP-WORKING UNDESIRABLE TREES.

The healthy unproductive lemon trees of undesirable strains in bearing orchards can usually be successfully top-worked through the use of bud wood selected from desirable and superior performance-record trees. Figure 18 shows two such bud sticks before they have been cut from the parent tree. Three bud sticks cut from the tree and ready for use are illustrated in figure 19.

The top-working is usually best done during the months of April, May, and June. As a rule, in the instances under observation, the best results have been obtained during May and early June. Fall top-working is not usually done on account of possible frost damage to the tender growth, except that it is the practice of some growers to insert buds in the trees to be top-worked during the late fall and allow the buds to remain dormant until spring. The advantage claimed for this method is that if any of the buds do not unite with the limbs in which they have been inserted and die during the winter new buds can be used in the spring, resulting in a more uniform stand than with spring budding. Observations during the course of these investigations do not bear out this contention, so that spring budding is strongly recommended for top-working.

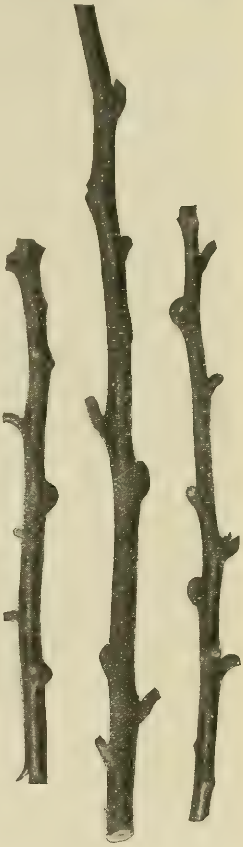

FIG. 19.—Typical fruit-bearing bud sticks from a lemon tree of the Eureka strain. The bud sticks after being cut and trimmed should be packed in slightly moistened sphagnum moss and held in a cool room until needed for use. (One-half natural size.)

The trees selected for top-working should be so pruned as to allow free access to the limbs in which the buds are to be inserted, as shown in figure 20. The limbs for top-working should be selected from the standpoint of furnishing a strong and suitable framework for the new tops. Usually from three to five such foundation limbs are necessary for the best results. The best place for the insertion of the buds on the limbs is usually from 1 to 2 feet from the fork of the branches. The best results are usually obtained by using two buds for each limb and inserting them near the under side of the limb.

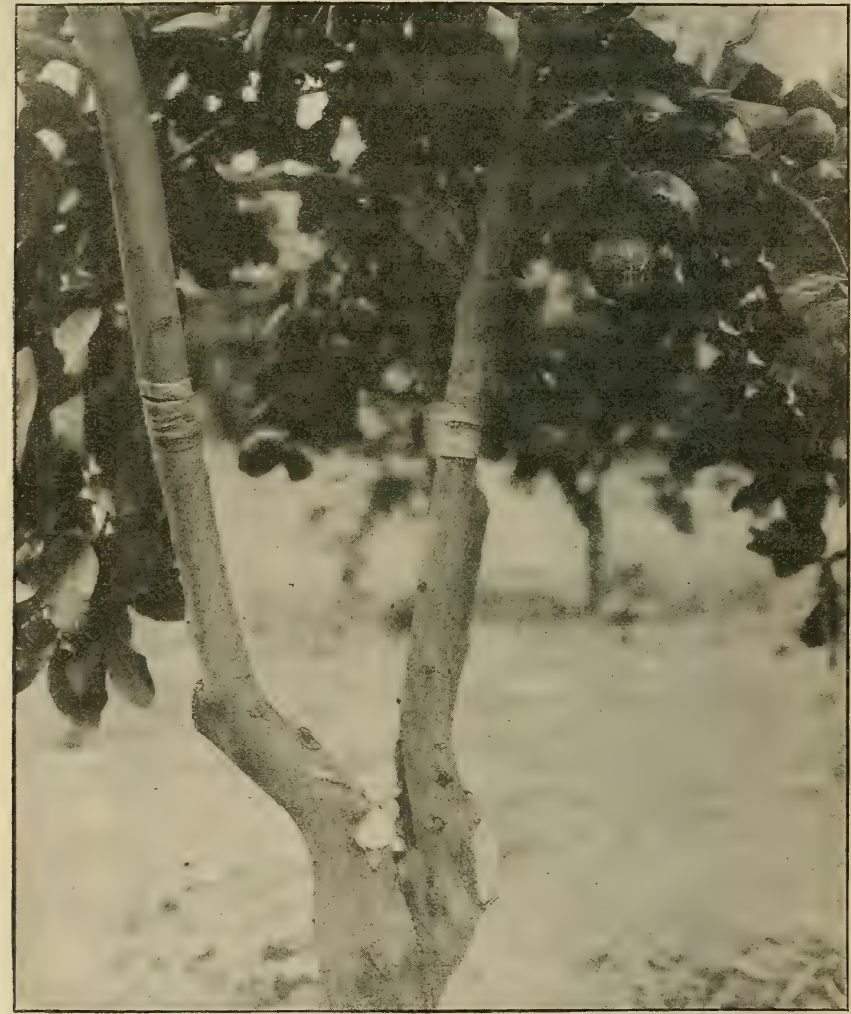

FIG. 20.—An undesirable lemon tree of the Eureka variety rebudded with select buds from fruit-bearing wood, showing the pruning of the tree preparatory to budding, position of the buds, and method of wrapping the buds with strips of waxed cloth.

At least one of the two buds on each limb is likely to develop, so that a perfect stand can usually be secured in this manner. With old trees having a thick bark the space where the buds are to be inserted should be thinned down with a sharp knife. In the case of older trees having very heavy bark the bark should not only be thinned down but a small section of it should be removed where the bud is exposed. This precaution frequently prevents the thick bark from growing over the inserted bud and killing it.

In from 10 days to 2 weeks after the buds have been inserted they will have united with the limbs, and the wounds in the limbs will have healed. At this time the limbs in which the buds have been placed should be cut off about 6 inches above the buds and all other limbs removed from the trees. In some instances one limb, in addition to those which were budded, is allowed to remain for a year after budding, in order to preserve somewhat the balance of the tree and to act as a nurse limb, so to speak, for the budded limbs.

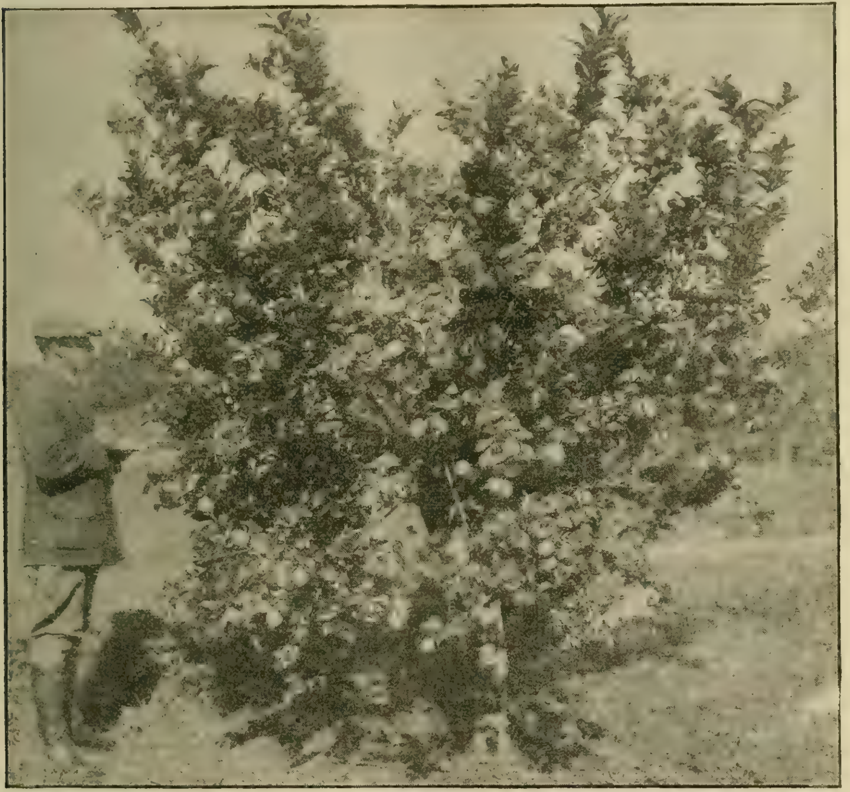

FIG. 21.—A typical lemon tree of the Shade-Tree strain of the Eureka variety, top-worked with fruit-bearing bud wood from a tree of the Eureka strain in June, 1911. The original unproductive top has been replaced with a productive one bearing fruit of the finest quality. The freeze of January, 1913, severely injured this tree and retarded its development. Photographed in February, 1915.

When the limbs have been cut off, the cut surfaces should be covered immediately with grafting wax, asphaltum, or other protective material. The trunk and parts of the limbs left after cutting should be thoroughly coated with whitewash, in order to protect them from injuries due to sunburn. After a year the stubs of the rebudded limbs should be cut back again, making a smooth sloping cut and leaving only one sprout from one bud on each limb. The cut surfaces should again be covered immediately with some protective material.

For two or three years after top-working, great care must be used in order to remove all growth other than that from the buds inserted in the limbs, otherwise the new top is likely to be made up partly of sprouts from the trunk and limbs instead of wholly from the selected buds, and the object of top-working be thereby defeated. Under normal conditions the growth from the selected buds in the top-worked trees will begin bearing lemons in the second year and during the third and fourth years will produce profitable crops (fig. 21).

REPLACING UNDESIRABLE TREES IN BEARING ORCHARDS.

In some instances it is desirable to remove the unproductive, unhealthy, or otherwise undesirable trees in full-bearing orchards and replant with reliable trees grown from selected buds rather than to top-work them. Until recently such replanting has frequently been unsuccessful. Experience has shown, however, that such undesirable trees can be removed and reliable trees substituted for them, when careful attention is given to a few fundamental requirements in providing the proper conditions for the young trees.

The trees selected to be taken out should be removed during the late summer or early fall. Excavations should be made for the new trees immediately after the older trees have been taken out. In this work holes should be dug about 5 feet in diameter and from 2 to 3 feet in depth. The holes should be filled with good topsoil, mixed, if possible, with well-rotted manure. They should be left in this condition during the winter and early spring so that the loose soil and manure in the holes will settle into position. The holes should be filled so that after settling the filling will stand at least 6 or 8 inches above the level of the land in the orchard. In this way any future settling will be provided for, and the new trees will eventually stand in the same position with reference to the surface of the land as the remainder of the trees in the orchard.

In the spring when the young trees are planted in the places provided for them, care must be taken to see that they are given sufficient water during each irrigation. This is usually best done by making a special irrigation furrow alongside or around each tree. It is also advisable to give the replanted trees small applications of some quickly available nitrogenous fertilizer, in order to stimulate early growth.

With large, well-prepared planting holes, adequate irrigation, and additional fertilization, the replanted trees will grow in bearing orchards about as well as though planted alone. Sometimes it is advisable, particularly in the case of close plantings, to dig trenches midway between the bearing trees and the replanted ones and fill them with manure. This precaution will enable the young trees to establish themselves without competition with the roots from the older trees.

THE SELECTION AND CARE OF BUD WOOD.

Bud wood should be taken only from trees whose behavior has been recorded by means of performance records. The selection of the parent trees should be based not only upon their performance records but also upon intimate tree knowledge developed from careful observation and experience with the variety, the strain, and the individual trees. Fruit-bearing bud wood should be taken only from superior trees. The buds from this immature bud wood make as satisfactory growth as those taken from larger growth or more mature wood. The lemons attached to each bud stick indicate the type of fruit propagated and insure so far as possible against the use of buds from sporting or un-

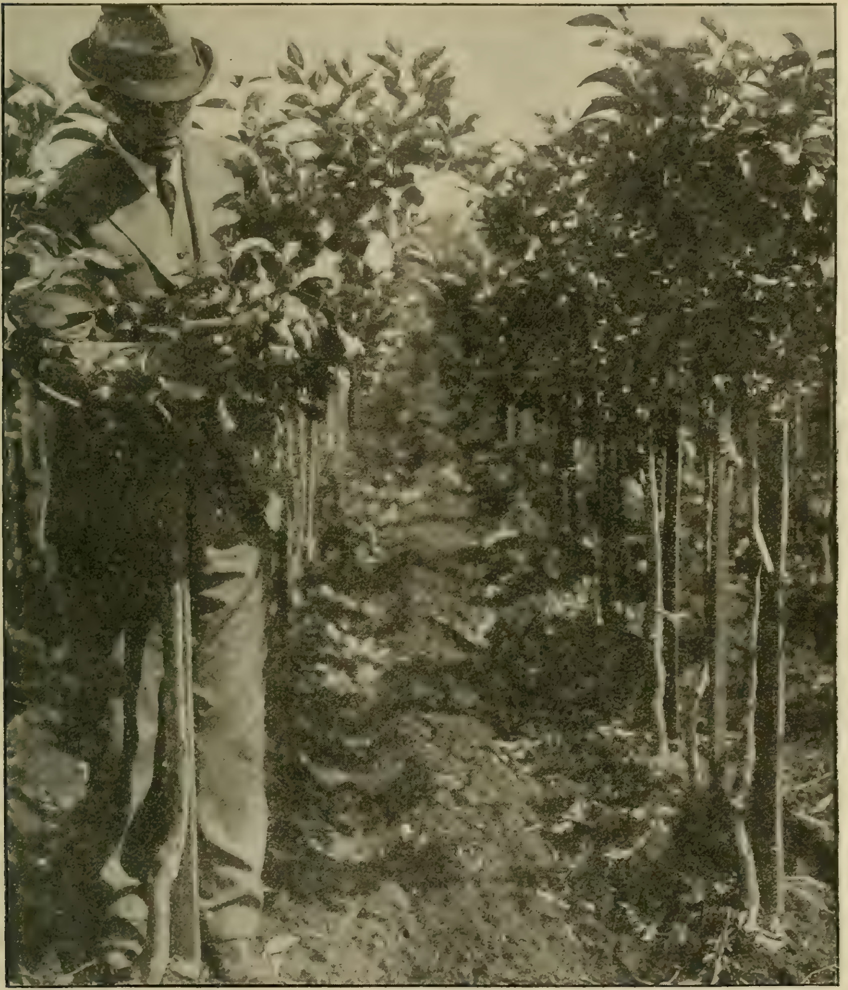

FIG. 22.—Nursery trees grown from fruit-bearing lemon bud wood of the Eureka strain, two years after budding, showing the vigorous growth and early fruiting tendency of trees propagated from such buds.

desirable branches. More buds can be cut from productive trees if this method is followed than from unproductive ones. Sufficient evidence, both experimental and practical, has been obtained to warrant the statement that fruit-bearing bud wood from productive trees is the most desirable kind to be used for propagation. The vigorous growth and early-fruiting tendency of nursery trees grown from such bud wood are illustrated in figure 22.

After the bud sticks have been cut the leaves and fruits should be clipped off, as shown in figure 19, and the bud sticks from each tree tied in a separate bundle with the number of the tree marked on one of the bud sticks or on a suitable label tied to the bundle. In this way the progeny of each tree can be kept separate if desired.

As soon as the bundle of bud sticks is obtained it should be wrapped in some moist material, commercial sphagnum moss being suitable for this purpose. In moistening the dry moss, either of two methods may be followed. The moss can be moistened safely by adding about half an ounce of water to each ounce of dry moss, or it may be steamed or soaked in water, after which it should be run through a clothes wringer so adjusted as to bring the greatest possible pressure to bear on the moss.

If the bud sticks are to be kept for some time before being used they should be stored where the temperature is about 70° F. and does not fluctuate greatly at any time. Under these conditions the bud wood may be kept in good condition for several weeks.

In May, 1917, the California Fruit Growers' Exchange, a cooperative organization of about 8,000 citrus growers, established a bud-selection department as a result of these investigations. The purpose in the organization of this department is to provide adequate and reliable sources of bud wood of citrus varities, including lemons, for use by all growers and propagators. As this department was established as a matter of public service and for the benefit of the citrus industry as a whole, the buds are distributed at cost to those who apply for them, whether the applicants are members of the exchange or not. The buds are taken only from trees selected on the basis of their performance records for several successive seasons. The orchards for this purpose are selected for their known production of superior crops of valuable fruits.

In obtaining commercial supplies of reliable bud wood from the superior individual trees of the best strains in the orchards finally selected for this purpose, the purchaser has the opportunity of visiting and studying the trees from which bud wood is to be cut, inspecting the records of the individual trees, and examining the fruits produced by them.

In cutting the bud wood from the carefully selected trees only fruit-bearing wood is chosen. The fruits from the bud sticks are returned to the owner of the trees. Each lot of bud sticks from each tree is tied in a bundle and the number of the parent tree or a key number is attached to it. In this way the propagator, if he so desires, can keep the progeny of each parent tree separate.

The bud sticks are cut only by men trained in this work, so as to avoid the danger of cutting bud wood from variable branches and to insure against mistakes in choosing the bud wood. The bundles of bud sticks are packed in properly moistened, sterile, sphagnum moss and delivered to the propagators as soon as practicable, in order to avoid possible injuries from storage. In this way trees of the best lemon strains are being propagated, so that the production from orchards planted with these trees can reasonably be expected to be uniformly of the best type and quality, thus insuring the best possible economic results to both the producers and the consumers.

SUMMARY.

The important commercial lemon varieties now grown in California are the Eureka, Lisbon, and Villa Franca. The Eureka variety originated from a seedling in the city of Los Angeles about 1860.

Several important strains of each of the varieties have arisen through the unintentional propagation of bud variations. In this bulletin only the variations within the Eureka variety are discussed. Descriptions of variations in the Lisbon lemon will be found in United States Department of Agriculture Bulletin No. 815.

Bud variations are of frequent occurrence in some of the trees of the Eureka variety. They are of great importance to the lemon industry in that some of the strains which have developed from them are inferior in quantity and quality of production. Bud variations are much more common in lemon varieties than has heretofore been thought to be the case. They occur as variations in the habit of tree growth, in the characteristics of foliage and blossoms, and in the color, shape, size, texture, juiciness, and other characteristics of the fruits.

The object of these investigations has been to determine the behavior of the trees of the different strains and of the individual trees within the strains, to develop practicable methods for eliminating undesirable trees in established orchards, to prevent the propagation of inferior strains, and to isolate and propagate the superior ones through bud selection based on individual-tree performance records and on intimate tree knowledge.

The plan of work in these investigations has been to secure individual-tree performance records in carefully selected plats of the Eureka variety where the conditions are most favorable for obtaining reliable and comparable data.

The method of keeping the individual-tree performance records is to pick each tree separately, assort the fruits, count and weigh them; make descriptive notes, photographs, and drawings of the trees, foliage, and fruits; and record these data so that after an adequate number of studies have been made conclusions as to varietal, strain, and tree behavior can be safely drawn.

In these investigations eight strains of the Eureka lemon have been studied, their characteristics described, and the performance of typical individual trees recorded.

Some of the lessons taught by these studies include the discovery of the importance of bud variations and the comparative value of the different strains arising from them, the necessity for and methods of isolating the valuable strains and eliminating the unprofitable ones through bud selection, the determination of the characteristics of the trees, flowers, and fruits of the different strains, and the origination and introduction of improved methods of propagation for conserving and improving the production of the lemon industry.

The desirable strains can be isolated through bud selection based on tree-performance records and intimate tree knowledge.

Undesirable healthy trees in established orchards can usually be successfully top-worked by the use of carefully selected buds.

The undesirable unhealthy trees can be replaced in established orchards through replanting with desirable ones when proper attention is given to the preparation of the planting holes and adequate care in irrigation and fertilization is given to the individual trees.

Only fruit-bearing bud wood from superior parent trees selected on the basis of their performance records and intimate tree knowledge should be used for propagation or for top-working.

In California, as a result of these investigations a department of bud selection has been established by the California Fruit Growers' Exchange, a cooperative organization of citrus growers, whereby reliable bud wood from superior performance-record lemon trees can be obtained by all growers and propagators.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 814

Office of the Secretary
Contribution from the Office of Farm Management
H. C. TAYLOR, Chief

Washington, D. C. ▼ April 24, 1920

THE STANDARD DAY'S WORK IN CENTRAL ILLINOIS.

Performance of Implements and Crews as Indicated by Reports from 600 Farmers in a Typical Corn-Belt Area.

By H. R. TOLLEY, *Scientific Assistant;* L. M. CHURCH, *Assistant in Farm Accounting.*

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INTRODUCTION.

Data regarding the amount of work that farm implements, teams, and crews may reasonably be expected to do are of value—

1. In determining the equipment that should be used on farms of various types and sizes.
2. As a guide to the farmer who plans to locate where farming conditions are unfamiliar.
3. As a guide to the farmer who plans to change the size of his farm or his type of farming.
4. As offering the investigator more or less assistance in determining the amount and value of work necessary in the production of crops.

During the winter of 1918 and 1919 reports were obtained from nearly 600 farmers in McLean County, Ill., concerning the rate of doing work with the farm implements, teams, and crews in use there. Each of these farmers gave his estimate of an average day's work on his place for each of the field operations, and the average time required for the operations not directly measurable in terms of a day's work. The results of this inquiry are set forth in the following pages.

It will be understood that the averages here presented are to be considered as representing, in each instance, but one factor of several that must be taken into account in working out any particular problem with regard to farm implements, teams, and workmen. Size of farm, distribution of labor, cost of operation, etc., must be known before specific application can be made of these figures. They indicate what is actually being accomplished in the average farm practice of the area. It is for the individual farmer to judge, by applying the data in the light of his own peculiar conditions, whether he is getting efficient service from his machinery and crews, and whether they are of the best size for his purpose.

While these data are strictly applicable perhaps only to the McLean County area, the practices followed on the farms in question are so typical of those of a large and widely distributed class of Corn Belt farmers that the results may be assumed to apply, at least in a broad way, to all parts of the Corn Belt where soil and conditions in general are comparable. It should be borne in mind that the figures presented do not represent actual, recorded performance, but are averages derived from careful estimates made by the 600 farmers who contributed to the making of this study.[1]

In the latter part of the bulletin figures for various farm operations, as determined by this study, are shown in comparison with figures for the same operations in western New York, as determined by a like study made there some years ago.

SUMMARY OF RESULTS.

The outstanding facts brought out by this inquiry are summarized in Table I. By reference to this table one may learn at a glance the average number of acres covered per day by these Illinois farmers in the different operations, according to size of implement or team, or the average number of minutes required per load in handling hay, ear corn, oats, and manure.

TABLE I.—*Summary of performance of implements, workmen, and crews in most common use in central Illinois.*

Implement or operation.	Size.	Horses.	Men.	Acres per day.
Sulky plow:				
Spring plowing	16 inches	3	1	3.02
Fall plowing	do	3	1	2.58
Gang plow:				
Spring plowing	28 inches	5	1	5.15
Fall plowing	do	6	1	4.71
Tractor plow:				
Spring plowing	42 inches		1	8.67
Fall plowing	do		1	8.06
Disk harrow:				
Well-packed land	8 feet	4	1	17.4
Freshly-plowed land	do	4	1	15.5

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[1] Experience has shown that the variation in such estimates is no greater than the variation in the results of efforts to obtain precise records by actual observation of farm operations, watch in hand. This latter method was tried out by the Office of Farm Management several years ago and discarded as impracticable. (See Dept. Bul. 3, "A Normal Day's Work for Various Farm Operations," p. 5.)

TABLE I.—*Summary of performance of implements, workmen, and crews in most common use in central Illinois*—Continued.

Implement or operation.	Size.	Horses.	Men.	Acres per day.
Spike-tooth harrow	20 feet	4	1	40.6
Corn planter:				
Check rower	42 inches	2	1	17.8
Drill	do	2	1	20.0
Corn cultivator:				
One-row riding	do	2	1	7.8
Two-row riding	do	3	1	13.5
Cutting and shocking corn by hand			1	1.28
Corn binder		3	1	7.66
Shocking corn after corn binder			2	6.66
Husking corn from standing stalks		2	1	1.67
Mechanical picker		5	1	6.8
Endgate seeder	35 feet	2	1	52.1
Grain drill	8 feet	4	1	14.9
Grain binder	do	4	1	17.9
Shocking oats			2	17.4
Mowing machine	5 feet	2	1	10.4
Tedder	10 feet	2	1	20.8
Sulky rake	do	2	1	20.8
				Minutes per load.
Unloading ear corn:				
With scoop shovel	42 bushels		1	28.1
With portable elevator	do		1	7.8
Unloading oats:				
With scoop shovel	85 bushels		1	25.6
With portable elevator	do		1	7.9
Loading hay:				
By hand	1.2 tons	2	3	31.4
With rake hay loader	do	2	3	23.2
Unloading hay into mow:				
By hand	do		3	41.0
With hay fork	do		4	18.2
Hauling and spreading manure:				
With spreader	65 bushels	3	1	45.6
With wagon box	44 bushels	2	1	68.4

GENERAL CONDITIONS.

Most of the farms in the area covered by this study are level, the soil is free from stumps and stones, and the fields are regular in shape. This permits more efficient use of farm machinery, especially of the larger sizes, than is possible in some sections of the country. The average size of all the farms from which the reports were obtained is 199.5 acres. An average of 32.1 acres per farm is never planted to crops, thus leaving an average crop area of 167.4 acres per farm. The land not planted to crops consists usually of the farmstead, roads, lanes, and possibly a small permanent pasture and wood lot. Corn is the principal crop, at least one-half of the crop area being devoted to the growing of this cereal. The oat crop is next in importance. Hay, mostly clover and timothy, and pasture in rotation, together occupy approximately the same acreage as oats. The most common rotation is (1) corn, (2) corn, (3) oats and (4) clover, or clover and timothy.

The average weight of the horses found on these farms is 1,355 pounds. On nearly two-thirds of the farms the horses weigh from 1,300 to 1,400 pounds, only a small percentage weighing less than 1,100 or over 1,500. These horses are considerably heavier than those usually found on eastern farms. Thus a team of a given number of horses will do more work per day here than in the East when pulling implements of heavy draft, particularly plows and disk harrows, but probably the difference in weight has no effect on the amount of work done per day with lighter implements such as corn planters and cultivators. As far as could be determined from the reports received, the variation in the weight of the horses found on these Illinois farms was not great enough appreciably to affect the rate of doing work.

The average time spent in the field, exclusive of the time required in going to and returning from the field in the morning, at noon, and at night, as reported by these men is 10 hours and 10 minutes per day for spring work and corn cultivation; 9 hours and 55 minutes for haying and grain harvest; 9 hours and 30 minutes for fall plowing and preparing ground; and 9 hours and 20 minutes for corn harvest.

On most of these farms the keeping of live stock is not an important enterprise, and thus it is possible for the workmen to spend longer hours in the field than would be the case in a section where live stock, especially dairy cows, are kept in large numbers.

PLOWING.

Walking plows are used to such a limited extent in the locality studied that no attempt was made to obtain data concerning their operation. About 80 per cent of the farmers reported the use of sulky plows, about 80 per cent stated that they use horse-drawn gang plows, and 14 per cent reported the use of tractors for plowing.

The depth of plowing in the spring averages about 5.3 inches. Most of the men reported plowing from 5 to 6 inches deep in the spring, less than 5 per cent of them indicating a depth as great as 7 inches, and not over 15 per cent reporting less than 5 inches. The variations in depth are apparently not sufficient to affect the amount of work done per day.

The plowing was usually about 1 inch deeper in the fall than in the spring, more than 80 per cent of the men reporting depths of from 6 to 7 inches, and some reporting 8 inches. The average is 6.5 inches.

SULKY PLOW.

SPRING PLOWING.

The acres covered per day by 14- and 16-inch sulky plows in spring plowing are given in Table II. It will be seen from this table that a large majority of the farmers use 16-inch sulky plows, that nearly all of them are operated with three horses in the spring, and that 3 acres is an average day's work for this outfit.

TABLE II.—*Spring plowing with sulky plow.*

Width of plow.	Number of horses.	Number of reports.	Acres per day	
			Average.	Acreage most often reported.
Inches.				
14	3	37	2.96	3 (*21 reports*).
16	3	355	3.02	3 (*221 reports*).
16	4	34	3.34	Scattering.

This table also shows that for the comparatively few farmers using 14-inch sulky plows with three horses in spring plowing about 3 acres is an average day's work. While theoretically the 16-inch plow should cover about 15 per cent more ground in the same length of time, this apparently has not been found true in practice. However, the fact that such a large percentage of the farmers use 16-inch plows shows that they are more satisfactory for this locality. The reports of the small number of farmers who use four horses on their sulky plows show that the fourth horse increases the efficiency of the outfit by a little over 10 per cent.

FALL PLOWING.

The performance of 3- and 4-horse teams with 14-inch sulky plows and 3-, 4-, and 5-horse teams with 16-inch plows is given in Table III. The greater frequency of the 4-horse teams and even the use of some 5-horse teams is accounted for by the fact that plowing in the fall is usually about 1 inch deeper than in the spring, and also by the fact that the ground is generally dry and hard to turn.

TABLE III.—*Fall plowing with sulky plow.*

Width of plow.	Number of horses.	Number of reports.	Acres per day.	
			Average.	Acreage most often reported.
Inches.				
14	3	16	2.48	2½ (*8 reports*).
14	4	20	2.75	3 (*9 reports*).
16	3	198	2.58	2½ (*95 reports*).
16	4	148	2.89	3 (*76 reports*).
16	5	16	3.20	Scattering.

On an average, outfits of the same size cover about a half acre less per day in the fall than in the spring, due not only to the more difficult conditions mentioned above, but also to the fact that the time spent in the field is about two-thirds of an hour less per day in the fall. As is the case in spring plowing, the 14-inch plow seems to cover practically as much ground per day as the 16-inch size, provided both are drawn by the same number of horses. The addition of the fourth horse increases the efficiency of the unit by about the same percentage as in the spring plowing, and the addition of the fifth horse to the 16-inch plow results in a similar increase. The fact that nearly one-half of the farmers reported the use of more than three horses indicates that in fall plowing, excepting under favorable conditions, a sulky plow is somewhat of an overload for three horses.

GANG PLOW.

Over 450 men reported using horse-drawn gang plows on their farms. About 80 per cent of these plows have 14-inch bottoms. Most of the remaining plows have 12-inch bottoms. Some plows with 13-inch bottoms were reported, but the number was so small that no figures on their performance are given. Over three-fourths of the men who use gang plows also reported the use of sulky plows.

SPRING PLOWING.

An average day's work for four and five horses pulling 12-inch gang plows cutting a total width of 24 inches, and four, five, and six horses drawing 14-inch plows cutting a total width of 28 inches, is given in Table IV. About an equal number use 4 and 5 horse teams on this implement. (See fig. 1.) The most common performance reported for both the 4 and 5 horse teams is 5 acres per day, although on an average the 5-horse teams drawing 28-inch plows cover about one-quarter of an acre more per day than do the 4-horse teams and plow to a slightly greater depth.

TABLE IV.—*Spring plowing with gang plow.*

Width of plow.	Number of horses.	Number of reports.	Acres per day.	
			Average.	Acreage most often reported.
Inches.				
24	4	24	5.02	5 (*15 reports*).
24	5	15	4.72	5 (*8 reports*).
28	4	148	4.92	5 (*87 reports*).
28	5	154	5.15	5 (*91 reports*).
28	6	68	5.40	5 (*30 reports*). 6 (*26 reports*).

The apparent inconsistency in the acres covered per day by the 4 and 5 horse teams with the 24-inch plows is probably due to the small number of reports entering into the average. Practically half of the men reporting on the 24-inch plows gave 5 acres as an average day's work, regardless of whether they used four or five horses.

FALL PLOWING.

Table V shows an average day's work in the fall for 5-horse teams with 24-inch plows, and 4, 5, and 6 horse teams with 28-inch plows. As compared with spring plowing, there is a marked increase in the use of 5 and 6 horse teams, this being due to the same conditions that cause the use of larger teams on the sulky plows in the fall.

TABLE V.—*Fall plowing with gang plow.*

Width of plow.	Number of horses.	Number of reports.	Acres per day.	
			Average.	Acreage most often reported.
Inches.				
24	5	20	4.40	4 (*10 reports*).
28	4	60	4.10	4 (*36 reports*).
28	5	118	4.56	4 (*45 reports*). 5 (*38 reports*).
28	6	153	4.71	5 (*73 reports*).

There is a decided decrease in the ground covered per day in the fall, the 28-inch plows and four horses accomplishing 17 per cent less than in the spring, the 5-horse outfits 11 per cent less, and six horses 13 per cent less. In fact, six horses cover on an average only as much ground per hour with these plows in the fall as do four horses in the spring.

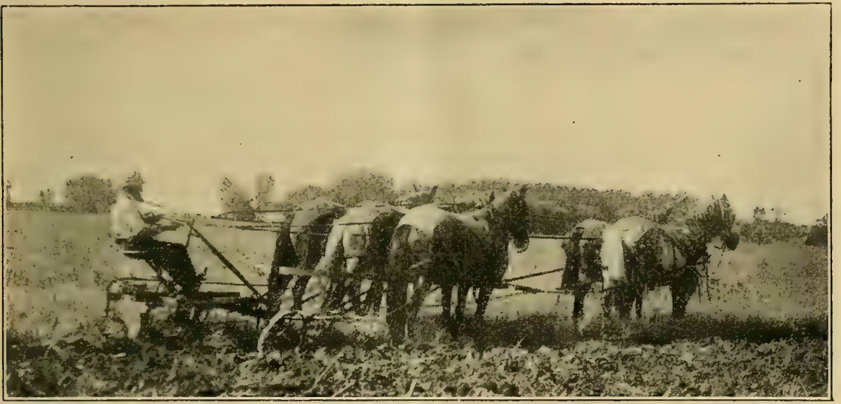

FIG. 1.—The 2-bottom gang plow, with 5 horses, covers a little over 5 acres per day in spring and 4.71 acres in the fall. This is a popular outfit.

COMPARISON OF SULKY AND GANG PLOWS.

A comparison of an average day's work for 16-inch sulky plows and 28-inch gang plows shows that so far as horse labor is concerned the gang plow drawn by four horses is the most efficient unit in both spring and fall. In the spring this outfit covers 1¼ acres per day per horse, while both the sulky plow drawn by three horses and the gang plow drawn by five horses cover 1 acre per day per horse. The gang plow drawn by six horses covers but nine-tenths of an acre per horse.

In the fall four horses with the gang plow cover 1.02 acres per horse, while three horses on the sulky plow and five horses on the gang plow cover .86 acre and .91 acre per horse, respectively. Four horses on the sulky plow and six horses on the gang plow cover .72 and .78 acre per horse, respectively. However, the gang plow is evidently a heavy load for four horses in the fall, excepting under favorable conditions. The 28-inch gang is a somewhat heavier load for six horses, the most popular sized team used in the fall, than is the 16-inch sulky for four horses, but is a lighter load than the 16-inch sulky for three horses.

As far as man labor is concerned, the gang plow drawn by six horses is, of course, the most efficient unit both in the spring and fall, but when horse labor as well as man labor is considered, it is seen that the advantage of this largest unit is somewhat lessened.

TRACTOR PLOWING.

Table VI shows the daily performance for both spring and fall of 2 and 3 bottom 14-inch plows pulled by tractors, as given by the farmers using power outfits.

TABLE VI.—*Tractor plowing.*

Width of furrow.	Spring.		Fall.	
	Number of reports.	Acres per day.	Number of reports.	Acres per day.
Inches				
28	19	7.00	21	6.38
42	42	8.67	46	8.06

A comparison of the work done by tractor-drawn plows cutting 28-inch furrows with that of plows of the same size drawn by horses, shows that in the spring the tractor does about 30 per cent more work per day than six horses, and in the fall about 35 per cent more, and that it does about 40 per cent more than four horses in the spring, and 55 per cent more than four horses in the fall. The tractors plowed to approximately the same depth, and worked approximately the same number of hours per day as did the horses.

The acres covered per day per plow are from 15 to 20 per cent less for the 3-plow outfits than for the 2-plow machines. As compared with the horse-drawn sulky plow, the 3-bottom tractor plow does on the average from two and three-fourths to three times as much as a 16-inch sulky drawn by three horses in the spring, or the same implement drawn by four horses in the fall. (See fig. 2.)

The reports of over 600 tractor owners throughout the State of Illinois as summarized in Farmers' Bulletin 963, "Tractor Experience in Illinois," showed an average of 6½ acres per day of 10 net working hours for 2-plow tractors and 8¾ acres for 3-plow machines. (Compare with Table VI.)

THE DISK HARROW.

The disk harrow is used on nearly every Corn-Belt Farm. Eighty-five per cent of the men from whom these reports were received own them. They are used for working up fall plowing in the spring and for preparing corn stubble for oats, as well as on freshly plowed ground. Practically all of these implements are single disks, and the 8-foot width is the most common, although the 7, 9, and 10 foot sizes are found on some farms. All of the men reporting 7- and 8-foot disks stated that they use four horses on them. Four horses were reported most often for the 9-foot size, although some farmers use five or six horses. Four, five, and six horse teams were reported for the 10-foot disk, the 6-horse team being the most common.

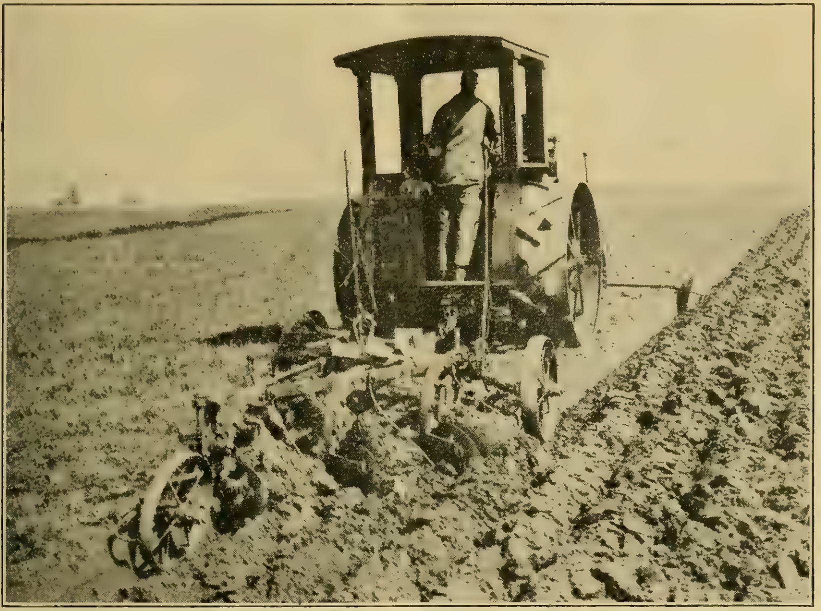

FIG. 2.—The 3-bottom tractor covers 8.67 acres per day in spring and 8.06 in the fall.

TABLE VII.—*Disk harrow on well-packed land.*

Width.	Number of horses.	Number of reports.	Acres per day.	
			Average.	Acreage most often reported.
Feet.				
7	4	52	15.4	15 (*13 reports*).
8	4	350	17.4	18 (*86 reports*). 20 (*91 reports*).
9	4	15	18.9	Scattering.
10	6	17	23.5	Do.

An average day's work in going once over well-packed land (without any lap) for 7, 8, and 9 foot disks, drawn by 4 horses, and 10-foot disks drawn by 6 horses, is given in Table VII. The average performance of the same units in going once over freshly plowed land (without any lap) is given in Table VIII.

TABLE VIII.—*Disk harrow on freshly-plowed land.*

Width.	Number of horses.	Number of reports.	Acres per day.	
			Average.	Acreage most often reported.
Feet. 7	4	60	14.3	15 (*25 reports*).
8	4	368	15.5	15 (*111 reports*).
9	4	15	16.9	Scattering.
10	6	23	22.7	20 (*7 reports*). 25 (*7 reports*).

Many farmers report that there is practically no difference between the rate of doing work on well-packed land and freshly-plowed land, as the disks must ordinarily be set at a somewhat greater angle in disking corn stubble or fall plowing, thus making the draft of the implement greater and overcoming the advantage of firmer footing for the horses. On an average, however, a day's work on well-packed land is from 1 to 2 acres greater than on freshly plowed land.

The 9-foot disk, drawn by 4 horses seems to be the most efficient unit so far as horse labor is concerned, this unit covering about 4.7 acres per horse per day on well-packed land, and 4.2 acres on freshly-plowed land. However, the fact that so many men are using 8-foot disks indicates that the 9-foot size is perhaps a slight overload for 4 horses.

A 10-foot disk makes the same load per horse for 5 horses as the 8-foot implement does for 4 horses, but most of these farmers who use 10-foot disks hitch 6 horses to them. While such an outfit permits one man to cover more ground per day than does any of the other units shown in the tables, the efficiency of the horse labor is less than when 4 horses are used with the 8-foot disk.

THE SPIKE-TOOTH HARROW.

Spike-tooth harrows ranging from 12 to over 25 feet in width were reported, and 95 per cent of the farmers stated that they hitch 4 horses to this implement. Fewer than 20 farmers using 3-section harrows, each section being from 4 to 5 feet wide, reported the use of 3 horses, and about the same number reported 5 and 6 horses for harrows 16 feet or more in width. (See Table IX.) Eighty per cent of these men use 4-section harrows, and about 50 per cent of these 4-section harrows have sections 5 feet wide, making a total width of 20 feet.

TABLE IX.—*Spike-tooth harrow (4 horses, once over, no lap).*

Number of sections.	Width of sections.	Number of reports.	Acres per day.	
			Average.	Acreage most often reported.
	Feet.			
3	5	61	33.0	30 (*18 reports*). 40 (*20 reports*).
3	6	23	36.5	40 (*12 reports*).
4	4	96	39.3	40 (*53 reports*).
4	4½	63	37.2	40 (*34 reports*).
4	5	166	40.6	40 (*93 reports*).
4	5½	13	41.9	40 (*5 reports*).

The acreage covered per day increases with the increase in width of the harrow, but not directly in proportion to it. While the larger harrows are most efficient from the standpoint of both man and horse labor, the 20 and 22 foot harrows cover on the average only 2 and 1.9 acres per day per foot of width, respectively, while the 15 and 16 foot harrows cover 2.2 and 2.4 acres per day per foot of width.

Out of 422 reports summarized in this table, 217 gave 40 acres as an average day's work. However, very few men using the smaller sizes reported over 40 acres, while 15 per cent of those using the 20 and 22 foot sizes said that on an average they covered 50 acres per day.

PLANTING CORN.

Except where the fields are small and irregular in shape, nearly all the corn in this region is checked, so that it can be cultivated in both directions. The 2-row planter with check-rower attachment is used universally for this work, about one-half of the farmers making the rows 40 inches apart and the remainder 42 inches. (See Table X.) Theoretically the amount of ground covered per day when the rows are 42 inches apart should be about 5 per cent greater than when the rows are 40 inches apart, but the figures show that on the average there was practically no difference on these farms.

TABLE X.—*Planting corn with check rower.*

Width of row.	Number of reports.	Acres per day.	
		Average.	Acreage most often reported.
Inches.			
40	259	18.0	20 (*105 reports*).
42	267	17.8	20 (*90 reports*).

The average performance of the 2-row planter in drilling corn, as reported by 136 farmers, is given in Table XI. Most of these men reported that they also used a check rower. As with the check rower there seems to be practically no difference between a day's work in drilling in rows 40 and 42 inches apart. However, on the average about 2 acres less per day are covered when checking than when drilling, this reduction in acreage being due probably to the time necessary to move and set the check-wire stakes, and the attention that must be given to the check-rower attachment.

Both in using a check rower and in drilling corn more men reported 20 acres per day than any other amount. However, the men using a check rower frequently reported from 15 to 18 acres as a day's work, and less than 3 per cent gave over 20 acres, while 25 per cent of the reports on drilling gave more than 20 acres.

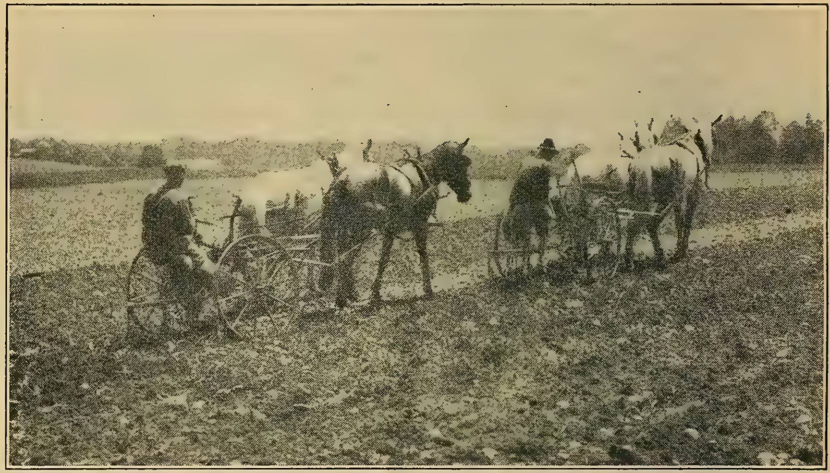

FIG. 3.—The 1-row riding cultivator, the most common type, covers 7.8 acres per day.

TABLE XI.—*Drilling corn with 2-row planter.*

Width of row.	Number of reports.	Acres per day.	
		Average.	Acreage most often reported.
Inches.			
40	68	19.6	20 (*30 reports*).
42	68	20.0	20 (*21 reports*).

CULTIVATING CORN.

Practically every farmer in the area uses the 1-row, 2-horse riding cultivator. (See fig. 3.) About 40 per cent of the men stated that they also use 2-row cultivators (fig. 4), though only two men reported the use of the 2-row machine exclusively. (See Table XII.)

TABLE XII.—*Cultivating corn with 1-row, 2-horse riding cultivator.*

Width of row.	Number of reports.	Acres per day.	
		Average.	Acreage most often reported.
Inches.			
40	244	7.9	7 (*48 reports*). 8 (*119 reports*).
42	264	7.8	7 (*61 reports*). 8 (*112 reports*).

It is usually not possible to make as good progress in the first cultivation as it is when the corn is larger, and sometimes difficulty is experienced in going crosswise in checked rows. However, no attempt was made to obtain figures applicable to these different conditions, the farmers simply being asked to give their estimates of an average day's work in cultivating corn.

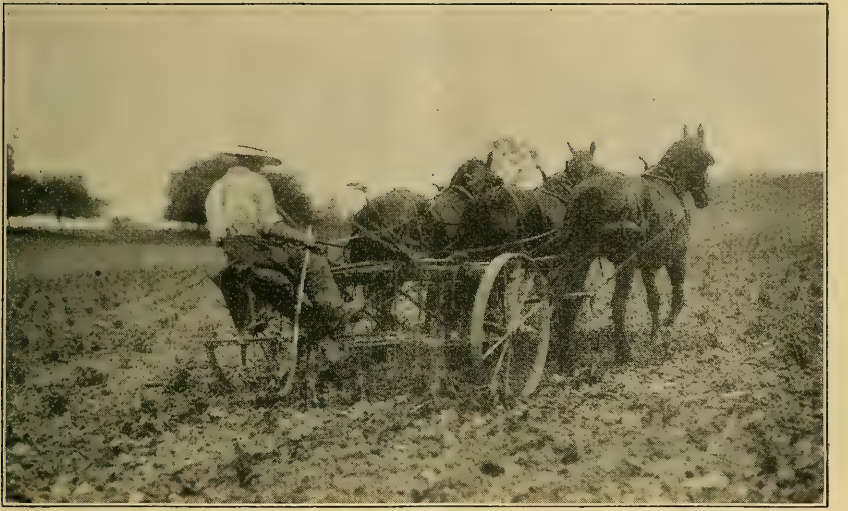

FIG. 4.—The 2-row cultivator covers on an average 13.5 acres per day, one and three-fourths times as much as the ½-row cultivator.

TABLE XIII.—*Cultivating corn with two-row cultivator.*

Width of rom.	Number of horses.	Number of reports.	Acres per day.	
			Average.	Acreage most often reported.
Inches.				
40	3	90	14.0	14 (*11 reports*). 15 (*31 reports*).
40	4	20	14.2	Scattering.
42	3	81	13.5	14 (*14 reports*). 15 (*19 reports*).
42	4	11	15.1	Scattering.

It will be seen (Table XIII) that a majority of the farmers using the 2-row cultivator hitch three horses to it. It is of comparatively light draft, and the addition of a fourth horse apparently increases but little the ground covered per day.

While the 2-row machine theoretically should cover twice as much ground per day as the 1-row, in practice it covers on the average only about one and three-quarters times as much. This comparatively lower rate of work is probably due to the greater difficulty experienced by the operator in handling the larger machine and the larger team.

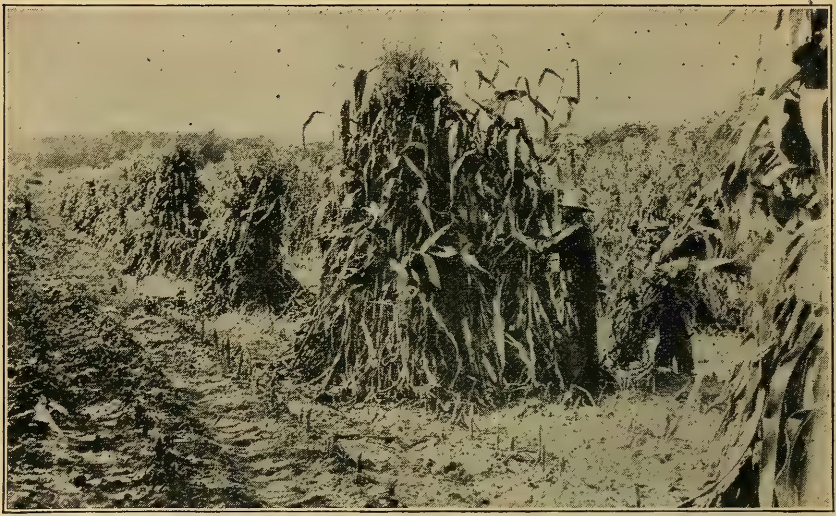

FIG. 5.—One man cuts and shocks by hand about 1.25 acres of corn per day.

About 65 per cent of the reports showed either 7 or 8 acres as an average day's work with the 1-row cultivator. About 55 per cent gave from 14 to 16 acres as a day's work for the 2-row implement, but only 6 per cent of them gave more than 16 acres.

CUTTING CORN.

The amount of live stock kept on these farms is small as compared to the amount of corn raised, and only a small part of the corn is cut either for fodder or ensilage, the remainder being husked from the standing stalks. Thus the work of cutting corn is not so well standardized as are some of the more important farm operations, and most of it is done by hand. Only about one-third of the farmers reported the use of corn binders.

CUTTING AND SHOCKING BY HAND.

Each of the farmers was asked to give his estimate of the amount of corn one man should cut and shock by hand in a day under varying conditions. Table XIV gives a summary of these estimates. Nearly all corn cut for fodder is put into shocks, either 12, 14, or 16 hills square, over two-thirds of the reports stating that it was the common practice to make shocks containing 196 hills (14 by 14). The most common performance reported when making shocks of this size was 20 shocks per day, but nearly as many men reported 25 and 30 shocks, practically three-fourths of the reports giving one or another of these three figures. (See fig. 5.)

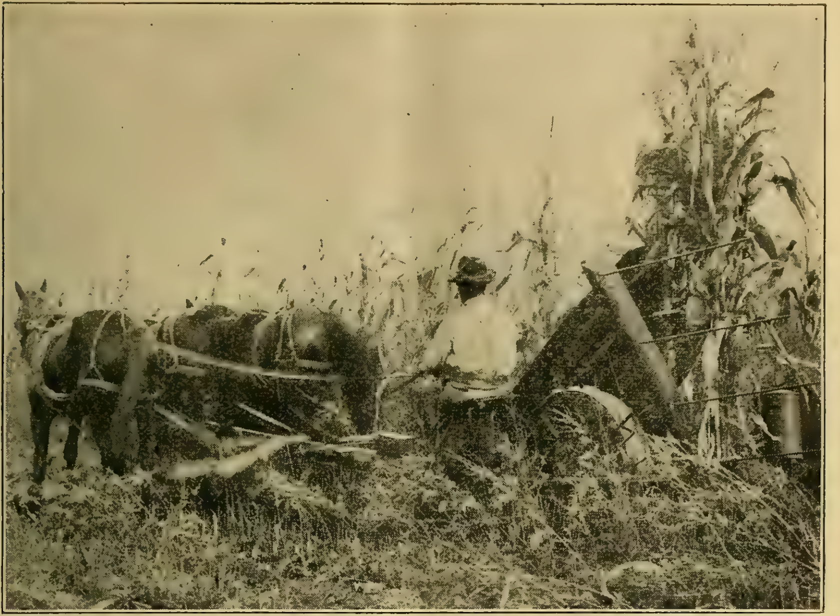

FIG. 6.—Where conditions are favorable, the corn binder increases the efficiency of man labor 50 per cent.

TABLE XIV.—*Cutting and shocking corn by hand (one man).*

Number of reports.	Size of shocks.	Acres covered per day.
292	144, 196, and 256 hills	1.28

Yields of from 40 to 65 bushels were reported, but the variations in yield apparently were not great enough to affect the ground covered per day.

THE CORN BINDER.

An average day's work for corn binders drawn by two, three, and four horses is given in Table XV. (See fig. 6.) A majority of the binders were drawn by three horses, this unit doing on an average about 10 per cent more per day than the 2-horse unit. More than half as many men reported the use of four horses as of three, but on the average the fourth horse increased the ground covered per day by less than one-tenth of an acre. Evidently the use of the fourth horse on this machine is not justified, excepting under unfavorable conditions.

TABLE XV.—*Cutting corn with binder.*

Number of horses.	Number of reports.	Acres per day.	
		Average.	Acreage most often reported.
2	20	7.00	Scattering.
3	112	7.66	7 (*25 reports*). 8 (*30 reports*).
4	59	7.74	7 (*14 reports*). 8 (*22 reports*).

SHOCKING CORN AFTER CORN BINDER.

The average performance of 2, 3, and 4 man crews in shocking corn after the corn binder is shown in Table XVI. The most common crew used in this work, two men, covers about three-fourths of an acre more per day per man than do the 3-man crews, and 1.2 acres more per man than do the 4-man crews. However, on the average, the 2-man crews lack about one acre per day of setting up as much corn as a corn binder drawn by three or four horses cuts. The 3-man crew shocks on the average just as fast as the corn binder cuts the corn, while the 4-man crew can shock three-fourths of an acre more per day than is cut by the binder.

TABLE XVI.—*Shocking corn after corn binder.*

Number of men.	Number of reports.	Acres per day		
		Average per crew.	Average per man.	Acreage per crew most often reported.
2	95	6.66	3.33	5 (*25 reports*). 6 (*24 reports*). 8 (*21 reports*).
3	57	7.74	2.58	7 (*14 reports*). 8 (*17 reports*). 10 (*14 reports*).
4	15	8.53	2.13	10 (*7 reports*).

One man with a corn binder drawn by three horses, and three men to shock the corn after the binder, cut and shock, on an average, 7.7 acres per day, or about 1.9 acres per man, while one man by hand cuts and shocks on an average 1.28 acres per day. Thus the corn binder and three horses increases the efficiency of man labor for this operation by nearly 50 per cent. If a two-man crew is used for shocking after the binder, and they cover 7 acres per day, the efficiency of each man is about 80 per cent greater than if they were cutting and shocking by hand. That more corn binders are not in use in this section is due to the fact that these machines are expensive, and the comparatively small amount of work for them to do, often less than a day per year, in a great many cases increases the cost per acre cut enough to offset this gain in efficiency of man labor.

HUSKING CORN.

Most of the corn grown in this section is husked from the standing stalk by extra help, which is paid at a fixed price per bushel. (See fig. 7.) The most common practice is to provide each workman with a wagon and team. Each man husks two loads of varying size per day, one in the morning and one in the afternoon, and hauls them to the crib and unloads them.

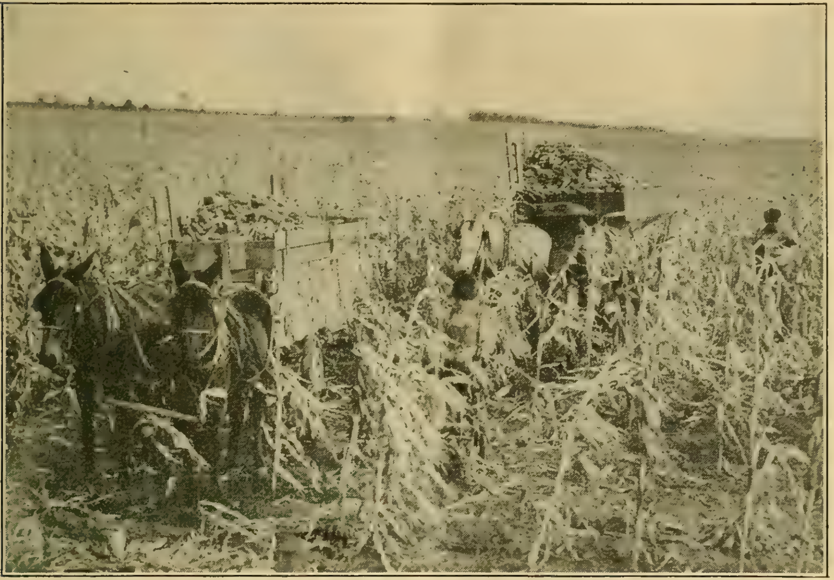

FIG. 7.—Most of the corn grown in McClean County is husked from the standing stalk.

TABLE XVII.—*Husking corn from standing stalks (1 man and team).*

Yield per acre.		Number of reports.	A day's work.		
Group limits.	Average.		Average.		Number bushels most often reported.
	Bushels.		*Bushels.*	*Acres.*	
40 to 45 bushels, inclusive	42.6	121	78.2	1.84	80 (*47 reports*).
46 to 55 bushels, inclusive	50.2	370	81.8	1.63	80 (*150 reports*).
56 to 65 bushels, inclusive	60.2	38	87.1	1.45	Scattering.
Average of total, all reports	49.2	529	81.3	1.67	

Table XVII gives the daily duty of one man when husking from the standing stalk, with corn of different yields. The average of 529 reports on this operation shows 81.3 bushels, or 1.67 acres, as a day's work. The number of bushels husked per day increases with the yield, but not in proportion to it. One man husks on an average 9 bushels more per day in corn yielding 60 bushels per acre than in corn yielding under 45 bushels, but covers four-tenths of an acre less ground. The individual estimates range from 50 to 100 bushels, but over 200 of the 529 men reporting gave 80 bushels as an average day's work.

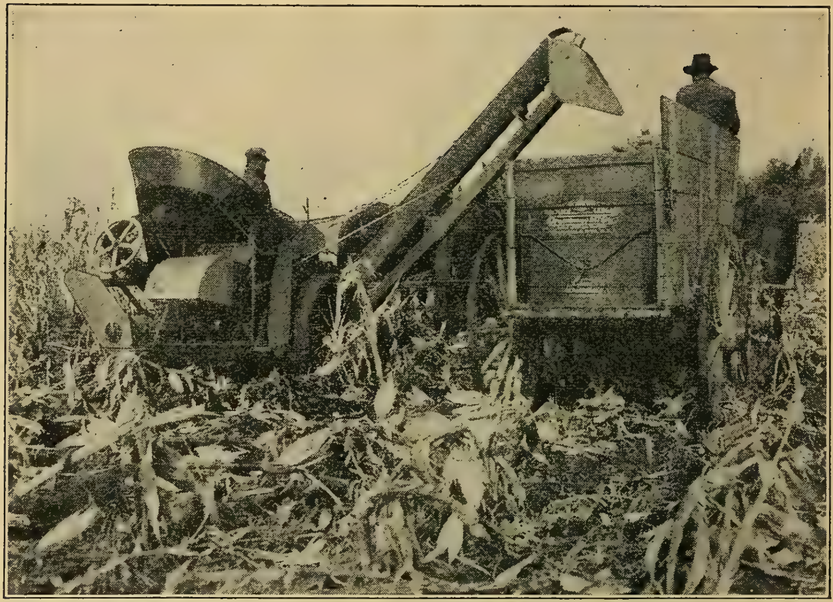

FIG. 8.—The mechanical picker increases the efficiency of man labor about 35 per cent, as compared with hand husking, but decreases slightly the efficiency of horse labor.

In this locality a bushel of ear corn is understood to consist of enough ears to make a bushel of shelled corn, the volume of a bushel of ear corn being approximately twice that of a bushel of shelled corn.

About one-tenth of the men reported the use of mechanical pickers for husking corn from the standing stalk. (See fig. 8.) Five or six horses are used to draw the machine, and from one to four men and teams were employed in hauling the corn from the field to the crib. The number of men and teams used for hauling the corn depends to a large extent upon the distance from the field to the crib and whether or not a portable elevator is used for unloading. Their crews are usually so arranged that the amount of corn husked and hauled depends almost entirely upon the ground covered by the picker.

Table XVIII shows an average day's work for 40 of these machines drawn by 5 horses, and for 20 machines drawn by 6 horses. The addition of the sixth horse apparently results in an increase of only about three-tenths of an acre per day.

TABLE XVIII.—*Husking corn from the standing stalks with a mechanical picker.*

Number of horses.	Number of reports.	Amount husked per day.	
		Bushels.	*Acres.*
5	40	336	6.8
6	20	351	7.1

Twenty-six of the 40 men who report the use of five horses on the picker used two men and teams for hauling to the crib, making a total crew of three men and nine horses. Their average performance was 333 bushels per day, or 111 bushels per day per man employed, and 37 bushels per horse. As compared with husking by hand as given in Table XVII, the mechanical picker, if used with a crew of this size, increases the efficiency of each man about 35 per cent but decreases the efficiency of the horse labor by about 10 per cent. The work for the men with the mechanical picker is not nearly so heavy and does not require so much skill as does husking by hand, while the work of the horses is a great deal heavier.

SEEDING GRAIN.

Regardless of the fact that numerous experiments have shown that oats which are drilled give better yields under most Corn Belt conditions than do those which are sown broadcast,[1] a large majority of the farmers still broadcast their oats, using end-gate seeders attached to the box of an ordinary wagon for this work. No small grain except oats is raised on most of the farms and only about 25 per cent of the farmers reporting have considered it worth while to buy grain drills.

END-GATE SEEDER.

The width of cast of these seeders as reported by the users varies from under 20 to over 40 feet. The majority of the farmers, however, reported using seeders which seeded strips of from 28 to 37 feet on each trip across the field. (See Table XIX.)

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[1] See Bulletin No. 136, University of Illinois Experiment Station, "Methods of Seeding Oats, Drilling, and Broadcasting." Also Farmers' Bulletin 892, "Spring Oat Production."

TABLE XIX.—*End-gate seeder.*

Width of cast.		Number of reports.	Acres per day.	
Group limits.	Average.		Average.	Acreage most often reported.
	Feet.			
18 to 22 feet inclusive	20.2	27	39.1	Scattering.
23 to 27 feet inclusive	25.8	34	44.0	Do.
28 to 32 feet inclusive	30.0	103	49.4	40 (*41 reports*). 50 (*18 reports*). 60 (*19 reports*).
33 to 37 feet inclusive	34.9	199	52.1	40 (*73 reports*). 50 (*32 reports*). 60 (*55 reports*).
38 to 42 feet inclusive	39.0	75	59.1	Scattering.

The acres covered per day increases with the width of cast but not in proportion to it, those sowing the narrowest strips covering almost 2 acres per day per foot of width, while the largest ones cover only a little over 1½ acres per day per foot of width. For the seeders in most common use, those sowing strips from 30 to 35 feet wide, approximately 50 acres is an average day's work. However, there is a considerable variation in the area covered by seeders with the same width of cast.

GRAIN DRILL.

The drills reported vary in size from the small 5-tube machines drawn by one horse, used in drilling winter wheat between the rows of standing corn, to wide implements having 20 to 24 tubes. The distance between tubes varies from 4 to 8 inches, but on nearly one-half of the machines they were 6 inches apart, and the 6 and 7 inch drills include three-fourths of the total number reported. Over 90 per cent of all the drills reported are disk drills. The average performance of disk drills with 16 tubes 6 inches apart, drawn by four horses, is given in Table XX. There were not a sufficient number of reports on any other unit to give a reliable average.

TABLE XX.—*Grain drill.*

Number of tubes.	Distance between tubes.	Number of horses.	Number of reports.	Average acres per day.
	Inches.			
16	6	4	24	14.9

The figures show that one man and two horses, with an end-gate seeder seeding a strip 35 feet wide, cover nearly three and one-half times as much ground per day as do one man and four horses with a 16-tube disk drill. However, the broadcasted grain must be covered, and to complete the operation the ground must be gone over with either a spike-tooth or disk harrow in addition to the end-gate seeder.

To go over the ground with both an end-gate seeder casting 35 feet, and a 20-foot spike-tooth harrow drawn by four horses (see Table IX) requires about two-thirds as much man labor and half as much horse labor as is required for the 4-horse, 8-foot drill. To go over the ground with the seeder and with an 8-foot disk drawn by four horses (see Table VII) takes 15 to 20 per cent more man labor and just about the same amount of horse labor as is required for the drill. As far as quality of tillage, aside from the seeding, is concerned, the work done by a disk drill should be somewhat better than that done by a spike-tooth harrow, but not so good as that done by a disk harrow.

HARVESTING GRAIN.

THE GRAIN BINDER.

Table XXI shows an average day's work for binders of different sizes in grain that is standing well. Oats sometimes lodge badly, especially in wet seasons, and when this condition exists a great deal of time is lost by the binder, the ground covered often being reduced by as much as 50 per cent. The actual time lost in particular cases, or the average condition of the oat crop in this respect at harvest time, is difficult to estimate, and the farmers were asked to give their experience only in grain that was standing well.

TABLE XXI.—*Grain binder.*

Width.	Number of horses.	Number of reports.	Acres per day.	
			Average.	Acreage most often reported.
Feet.				
6	3	19	13.3	Scattering.
7	3	17	14.0	Do.
7	4	30	15.2	15 (*15 reports*).
8	4	471	17.9	15 (*87 reports*). 18 (*107 reports*). 20 (*178 reports*).

The table shows that a large majority of the men use 8-foot binders drawn by four horses. The averages indicate that the 7-foot machine drawn by three horses is the most efficient unit with respect to horse labor, 4.7 acres per day per horse being covered with this outfit, as compared with 4.5 acres for the 8-foot binder drawn by four horses and 4.4 acres for the 6-foot machine with three horses. While the fact that two-thirds of the men who have 7-foot binders use 4-horse teams with them indicates that this machine is a heavy load for three horses, a 7-foot binder and four horses is the least efficient combination shown in the table, each horse accomplishing nearly 15 per cent less than those on either the 6 or 8 foot machines.

SHOCKING OATS.

The average performance of 2, 3, and 4 man crews in shocking oats is given in Table XXII. The reports show that two men constitute the customary crew for this work on nearly four-fifths of the farms, and that they do on an average 17.4 acres per day, or half an acre less per day than is covered by an 8-foot binder drawn by four horses. The efficiency of the labor decreases decidedly with the addition of extra men to the crew, three men working together covering 2 acres less per day per man than in a 2-man crew, and four men covering nearly 3 acres less per man. Part of this reduction in efficiency is due to the fact that it is customary for the shockers to follow around the field closely after the binder, and no matter how many men are used they can not shock any more grain in a given time than is cut by the binder after which they are working.

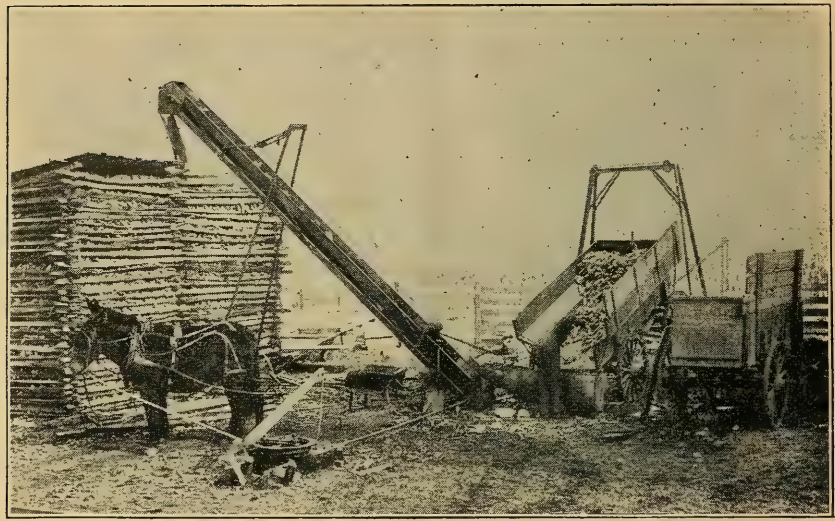

FIG. 9.—The portable elevator is generally used for unloading grain.

TABLE XXII.—*Shocking oats.*

Number of men.	Number of reports.	Acres per day.		
		Average per crew.	Average per man.	Average per crew most often reported.
2	400	17.4	8.7	15 (*102 reports*). 20 (*143 reports*).
3	101	20.0	6.7	20 (*47 reports*).
4	16	23.4	5.9	20 (*7 reports*).
	517	....	8.2	

The yield per acre of oats evidently has very little effect upon the amount of work done by the shockers. The average of 59 estimates for 2-man crews in oats yielding 45 bushels per acre or less gave 17.4 acres per day; 281 estimates of the same sized crew with a yield ranging from 46 to 55 bushels gave the same area, and 60 estimates with a yield over 55 bushels gave 17.2 acres per day.

UNLOADING GRAIN.

Portable elevators are in general use in this locality for unloading corn and oats into the crib and bin, and in order to make possible a comparison of the efficiency of this practice with that of unloading with a scoop shovel the farmers were asked to estimate the time required to unload ear corn and oats by the two methods. (See fig. 9.) No attempt was made to differentiate between the elevators operated by gasoline engines and those where horses furnished the power.

TABLE XXIII.—*Unloading grain by hand and with portable elevator.*

Kind of grain.	Number of reports.	Average per load.	Time required to unload.	
			By hand.	With elevator.
		Bushels.	*Minutes.*	*Minutes.*
Ear corn	484	42.5	28.1	7.8
Oats	482	85.3	25.6	7.9

Table XXIII shows that on the average the elevator saves about 20 minutes in unloading a load of corn and 18 minutes in unloading a load of oats. This saving in time, and the release from the hard labor of scooping grain is worth considerable, especially to men who are husking corn by the bushel. The most frequent size of load of ear corn reported was 40 bushels. The most frequent size of load of oats was 100 bushels, but no load greater than 100 bushels was reported. Ten minutes was given most often as the time necessary for unloading these loads with an elevator, while 30 minutes was given most often as the time for unloading them with a scoop shovel.

HAYING OPERATIONS.

Hay is not as important on these farms as corn or oats, most of the farms having under 20 acres in this crop. This is reflected in the machinery used for harvesting hay, most of the mowers and rakes being of the smaller sizes, and a comparatively small number of hay loaders being reported. Nearly all of the hay is either clover, timothy, or clover and timothy, very few men reporting alfalfa. A study of the reports showed that the kind of hay and variations in yield apparently have little effect on the efficiency of the machines and crews, and no attempt has been made to take these factors into account in the tables below. The average yield per cutting of all hay as given in these reports was 1.6 tons per acre.

MOWING.

Table XXIV gives the average acreage per day cut by 5 and 6 foot mowers. Only about 1 farmer in 40 reported the use of a 7-foot mower, and not one stated he was using an 8-foot machine. It will be seen that there are more than three times as many 5-foot mowers in use as 6-foot machines. As compared with the 5-foot mower, the 6-foot implement increases the efficiency of man and horse labor by about 15 per cent, and the 7 and 8 foot sizes would result in correspondingly greater increases. However, when mowing hay is such a small task, many farmers saying they have never used a mowing machine a full day, they evidently consider the investment in the larger and more expensive machines inadvisable. The smaller sizes are also more satisfactory for mowing weeds at the roadside and along fence rows.

TABLE XXIV.—*Mowing machine.*

Width of swath.	Number of reports.	Acres per day.	
		Average.	Acreage most often reported.
Feet. 5	322	10.4	10 (*158 reports*).
6	101	11.9	10 (*35 reports*). 15 (*27 reports*).

TEDDING.

About one-third of the farmers use hay tedders. Those reported range from 5 to 12 feet in width, and two horses are used on nearly all of them. An average day's work for the 8 and 10 foot widths is shown in Table XXV. There were not enough reports on any of the other sizes to give reliable averages. As both the 8- and 10-foot machines cover on an average a little over 2 acres per day per foot of width, the 10-foot tedder covers about 4 acres more per day than the 8-foot machine.

TABLE XXV.—*Tedder (2 horses).*

Width.	Number of reports.	Acres per day.	
		Average.	Acreage most often reported.
Feet. 8	77	17.0	15 (*20 reports*). 20 (*26 reports*).
10	58	20.8	20 (*27 reports*). 25 (*13 reports*).

RAKING.

The sulky rake is in much more common use than is the side-delivery rake, over 200 men reporting the use of sulky rakes, while less than 40 reported side-delivery machines. Nearly everyone uses two horses on these implements. (See Table XXVI.)

TABLE XXVI.—*Hay rakes (2 horses).*

Width.	Sulky.		Side-delivery.	
	Number of reports.	Average acres per day.	Number of reports.	Average acres per day.
10 feet	141	20.8	22	20.4
11 feet	22	22.0	....	....
12 feet	58	23.4	....	....

Most of the rakes are 10 feet in width, this size being best for use with the 5-foot mowers. About 20 acres is an average day's work for both the sulky and side-delivery rakes of this width, and just half of the men using rakes of this size estimated an average day's work on their farms to be 20 acres. Twenty acres is also reported most often for the 11 and 12 foot rakes, but on an average the 12-foot rakes are shown to cover about 2½ acres per day more than the 10-foot ones.

LOADING HAY.

Most of the hay is taken directly from the field to the mow. Very few sweep rakes or stackers are in use, and no attempt was made to secure data on them. The farmers were questioned only in regard to their experience in loading hay by hand and with the hay loader. Less than half the farmers reported the use of hay loaders. (See figs. 10 and 11.)

LOADING BY HAND.

The most common crew for loading by hand consists of two men to pitch and one man on the load. The only other crew reported by more than a small percentage of farmers consisted of but two men, one to pitch and one on the load. (See Table XXVII.) The average size of load is the same in both cases, 1.2 tons. The addition of the second man to pitch reduces the time required to put on a load by about 25 per cent. While the figures indicate that the two-man crew is slightly more efficient than are three men, the fact that a large majority of the crews consist of three men tends to show that this has been found to be a better arrangement when the entire haying operation is considered.

TABLE XXVII.—*Loading hay by hand (one man on load).*

Number of men to pitch.	Number of reports.	Minutes per load.	
		Average.	Time most often reported.
1	48	42.2	Scattering.
2	348	31.4	30 (*150 reports*).

HAY LOADER.

Table XXVIII gives the time required for two men besides the driver of the team to put on a load with the cylinder hay loader from the swath and from the windrow, and with the rake loader from the swath. More than twice as many men reported using rake loaders than those using cylinder loaders. Some reported the use of only one man on the load, but there were not enough of these to justify comparison between this practice and the using of two men. The table shows that, as far as time is concerned, there is very little difference between the efficiency of these two loaders. The average size of load put on with the loaders is 1.3 tons, nearly the same as that put on when the work is done by hand.

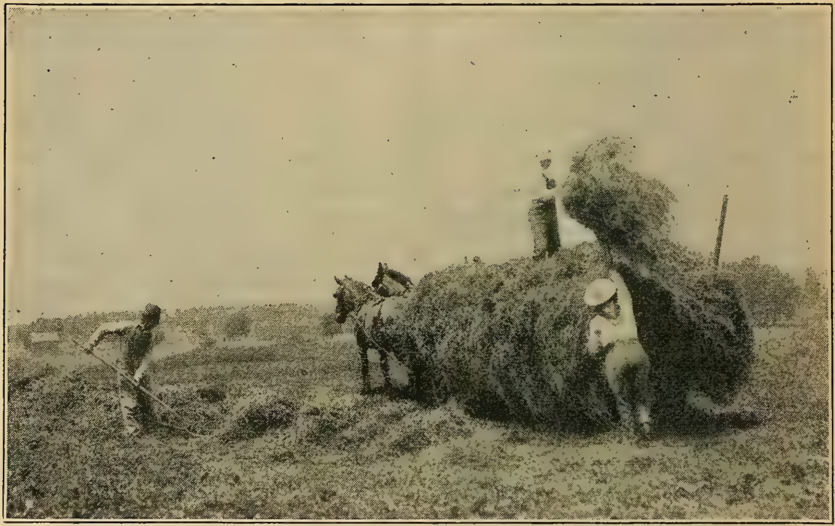

FIG. 10.—In loading hay by hand the 3-man crew is most often used.

As compared with loading by hand, three men with a loader—two besides the driver of the team—put on a load in about 25 per cent less time than do three men by hand. There is the added advantage that the services of some one who can not do a full man's work with the pitchfork can be utilized for driving the team. If the hay is loaded directly from the swath the operations of raking and bunching are of course entirely done away with when the loader is used.

TABLE XXVIII.—*Loading hay with cylinder and rake loaders (two men, besides driver of team).*

Kind of loader.	Loading from—	Number of men.	Number of reports.	Minutes per load.	
				Average.	Time most often reported.
Cylinder	Swath	2	17	21.9	Scattering.
Do	Windrow	2	27	22.0	Do.
Rake	Swath	2	80	23.2	20 (*27 reports*). 30 (*26 reports*).
Average, all reports				22.8	

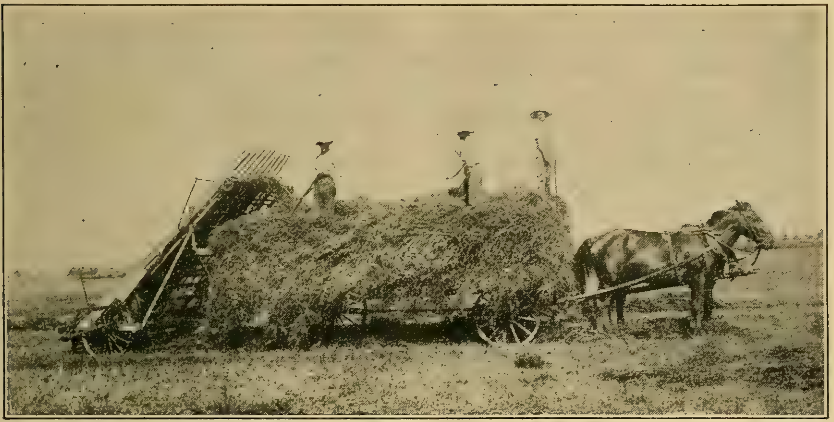

FIG. 11.—The hay loader reduces by about 25 per cent the time required to put on a load of hay.

Most of the hay racks in use here are 7 feet wide and 14 feet long. However, a considerable number 8 feet wide and 14 feet long, and some 7 by 16 and 8 by 16 feet were reported. The variations in the size of rack were evidently not great enough to affect the size of load.

UNLOADING HAY.

The farmers were asked to give their experience in putting hay into the mow both by hand and with a hayfork. (See Tables XXIX and XXX.)

UNLOADING BY HAND.

In unloading by hand the most common practice is to have one man on the wagon and two in the mow, and on an average it takes 41 minutes for this crew to unload a load of 1.2 tons. The table shows that it takes but very little longer for the 2-man crew, one man on the wagon and one in the mow, to put away a load. However, a crew of this size is ordinarily used only in small barns, or when very little moving of the hay in the mow is to be done. Under such conditions one man in the mow can take care of the hay as fast as the man on the wagon can pitch it off, and a second man in the mow can not lessen materially the time required for the work. The 4-man crew, two men on the wagon and two in the mow, seems to be less efficient than either the 2 or the 3 man crew. With this crew it requires a total of about two and one-quarter hours of man labor to unload a load as compared with two hours with the 3-man crew and less than one and one-half hours with the 2-man crew.

TABLE XXIX.—*Unloading hay into mow by hand.*

Number of men on wagon.	Number of men in mow.	Number of reports.	Minutes per load.	
			Average.	Time most often reported.
1	1	67	43.4	30 (*16 reports*). 60 (*18 reports*).
1	2	216	41.0	30 (*63 reports*). 40 (*46 reports*). 60 (*35 reports*).
2	2	92	33.2	30 (*33 reports*).

UNLOADING WITH HAYFORK.

The crew for unloading with a hayfork always consists of one man on the load, a man or boy to drive the horse or team on the hayfork rope, and enough men in the mow to take care of the hay as fast as it can be gotten to them. As was the case in unloading by hand, the smallest crew seems to be the most efficient. The 3-man crew, one man in the mow, one on the load, and one to drive the hayfork team, uses 20 per cent less man labor per load than does the 4-man crew, and 35 per cent less than the 5-man crew. However, the fact that such a large majority report the use of two men in the mow indicates that unless there is but little work to be done in the mow two men are necessary to keep up with the hayfork.

TABLE XXX.—*Unloading hay into mow with hayfork (one man on load and one driving hayfork team).*

Number of men in mow.	Number of reports.	Minutes per load.	
		Average.	Time most often reported.
1	64	20.2	Scattering.
2	364	18.2	15 (*112 reports*). 20 (*105 reports*).
3	23	16.4	15 (*9 reports*).

The total hours of man labor required for unloading with 3 and 4 man crews is only a little more than half as great when a hayfork is used as when the work is done by hand. Besides the direct saving of time a boy can drive the horses attached to the hayfork rope, and the work of the other men, especially the one on the wagon, is not as hard as when unloading by hand. The horses used on the hay-fork rope are usually the same as those used for drawing the hay from the field, and would be standing idle if the hay was unloaded by hand.

HAULING AND SPREADING MANURE.

In gathering data on the use of manure spreaders each farmer was asked to give the size of load ordinarily hauled (in bushels), the number of horses generally used, the most common distance hauled, and time required for one man to load, haul to the field, spread and return. The same information was obtained for hauling in a wagon box and spreading by hand. (See Table XXXI.)

The most common distance from the barn to the field reported was 80 rods, with an average of 75 rods for the spreader and 74 rods for the wagon. Sixty bushels was reported most often as a load for the spreader, but 50, 70, 75, and 80 bushels were each given as an ordinary load in more than 10 per cent of the reports. Thirty bushels was given most frequently as a load for the wagon, but 40, 50, and 60 bushels were each given as an ordinary load in from 10 to 20 per cent of the reports.

About 60 per cent of the farmers use three horses with the spreader, about 30 per cent use 4-horse teams and the remainder 2-horse teams. The size of the load and distance hauled, however, apparently have very little to do with the number of horses used. Two horses are nearly always used when hauling in a wagon.

TABLE XXXI.—*Hauling and spreading manure (time required to load, haul to field, spread, and return).*

	Number of reports.	Number of horses.	Distance hauled.	Size of load.	Time per load.
			Rods.	*Bushels.*	*Minutes.*
Wagon	312	2	74	44	68.4
Spreader	382	2,3,4	75	65	45.6

From Table XXXI it is evident that a given amount of manure can be handled in less than one-half the time with the spreaders in common use than with the wagons, the manure being handled at the rate of 1.4 bushels per minute with the spreader, and of less than seven-tenths of a bushel per minute with the wagon. The increase in efficiency is due not only to the saving in time when spreading the manure, but also to the fact that considerably larger loads are hauled in the spreaders and comparatively less time is spent in going to and from the field. Besides this saving in time the manure will usually be spread more evenly over the field, and the hard work of spreading with a fork is entirely eliminated.

COMPARISON OF ILLINOIS AND NEW YORK PRACTICES.

A comparison of the sizes of implements and teams in most common use in Illinois with those in most common use in western New York shows not only that larger teams and implements are in general use in Illinois, but that even where the implements and teams are of the same size one man in Illinois accomplishes more per day in nearly every operation than does one workman in New York.

Data regarding their rate of doing farm work were obtained from farmers of seven counties in western New York in 1915, and published in United States Department of Agriculture Bulletin 412, "The Normal Day's Work of Farm Implements, Workmen, and Crews in Western New York." With regard to the section where the data were obtained the bulletin says:

> The farm land is somewhat rolling, but not to an extent to reduce appreciably the average amount of work that can be done daily. Some of the heavier soils of the Dunkirk series can not be plowed as rapidly as can the more loamy soils of the Middle West. The presence of more or less stone throughout the section also operates to reduce the amount of work than can be done daily with plows. There are no local reasons why farm implements that are drawn over the land, like mowers, binders, rakes, etc., should not perform as much work daily here as anywhere. The horses used in western New York average 1,211 pounds in weight. The average net day in the field in spring and summer work was found to be 9 hours and 38 minutes, and in haying and harvest it is 9 hours and 49 minutes.

PLOWING, HARROWING, AND DISKING.

In Table XXXII are given figures for the most common sizes of implements and teams used in plowing, harrowing and disking, and the rate of doing work with them in the western New York area, together with similar figures for McLean County, Ill.

The daily acreages for plows in the Illinois area are averages of figures for spring and fall plowing from Table II to VI inclusive. The acreages for western New York are averages of figures for plowing on sod and plowing on stubble, as given in Bulletin 412. The daily acreages for the disk harrow for both areas are averages of its accomplishment on freshly plowed land and on well-packed land.

TABLE XXXII.—*Plowing, harrowing, and disking.*

Implement.	McLean County, Ill.			Western New York.		
	Most common size.	Number of horses.	Acres per day.	Most common size.	Number of horses.	Acres per day.
Walking plow				12-inch	2	1.56
Sulky plow	16-inch	3	2.80	14-inch	3	2.14
Gang plow	28-inch	5	4.85			
Tractor plow	42-inch		8.37	28-inch		[a] 4.50
Spike-tooth harrow	20-foot	4	40.60	8-foot	2	13.00
Disk harrow	8-foot	4	16.50	6-foot	3	9.00

[a] From Farmers' Bulletin 1004, "The Gas Tractor in Eastern Farming."

The most common unit for plowing in the western New York area is the 2-horse walking plow, and with it one man covers only about one-third as much ground per day as does one man with the 5-horse gang in central Illinois. Even with the 3-horse sulky, which is in use in both sections, the average accomplishment of these Illinois farmers exceeds that of those of the New York area by over 30 per cent. Part of this difference is doubtless due to the easier plowing conditions in Illinois, as mentioned above.

There is a greater difference between the acres covered per day by one man with the spike-tooth harrow in the two areas than with any other implement shown in the table, one man in central Illinois accomplishing over three times as much as one man in western New York.

OPERATIONS ON THE CORN CROP.

Table XXXIII shows in comparison the rates of doing work on the corn crop with the implements and crews in most common use in the two areas. The figures for planting apply to corn in rows 42 inches apart. In western New York corn is generally planted with the grain drill, this implement planting two rows at a time, covering about the same acreage per day as the two-row planter. The Illinois men use the planter exclusively for both checkrowing and drilling, and in drilling cover nearly twice as much per day as do the New Yorkers who drill with grain drills.

TABLE XXXIII.—*Operations on the corn crop.*

Implement or operation.	McLean County, Ill.			Western New York.		
	Most common size.	Number of horses.	Acres per day.	Most common size.	Number of horses.	Acres per day.
Grain drill				2-row	2	11.60
Corn planter (drill)	2-row	2	20.00	do	2	10.70
Corn planter (checkrower)	do	2	17.80			
Walking cultivator					1	4.10
Riding cultivator	1-row	2	7.80	1-row	2	7.10
Do	2-row	3	13.80			
Cutting corn by hand			1.28			1.12
Cutting corn with binder		3	7.66		3	5.70
Shocking corn after binder			2.97			3.35
Husking corn from standing stalks		2	1.67			
Husking corn from shock						.46

About a third of the reports from western New York stated that the corn was planted in rows 36 inches apart, the remainder being planted in rows 42 inches apart. The figures given in the table for western New York for the operations other than planting are averages of both sets of reports. The figures for the Illinois area are averages of the performance in corn where the rows are 40 and 42 inches apart.

On only one operation, that of shocking corn after the binder, do the western New York farmers accomplish more per man than do those in the Illinois area.

SEEDING AND HARVESTING GRAIN.

The sizes of implements and teams and the acres covered per day in drilling and harvesting grain, and the accomplishment of one man in shocking grain for the two areas are given in Table XXXIV. The larger implements and teams used in the Illinois area enable one man to cover more ground per day when seeding and harvesting grain, and each man covers a 10 per cent greater acreage in shocking in the Illinois area than he does in western New York. The figures for the binders and the shockers apply only to the oats crop in Illinois area, while those for western New York are averages for all grain.

TABLE XXXIV.—*Seeding and harvesting grain.*

Implement or operation.	McClean County, Ill.			Western New York.		
	Most common size.	Number of horses.	Acres per day.	Most common size.	Number of horses.	Acres per day.
	Feet			*Feet*		
Grain drill	8	4	14.9	6	2	10.0
Grain binder	8	4	17.9	6	3	10.4
Shocking			8.2			7.5

HAYING.

Table XXXV shows in comparison the work of mowers, tedders, and sulky rakes in the two areas. Five-foot mowers and 10-foot rakes are the most common sizes in both areas. It will be seen that all these implements cover more ground per day in the Illinois area than in western New York.

TABLE XXXV.—*Mowing, tedding, and raking hay.*

Implement.	McLean County, Ill.			Western New York.		
	Most common size.	Number of horses.	Acres per day.	Most common size.	Number of horses.	Acres per day.
	Feet			*Feet*		
Mower	5	2	10.4	5	2	9.0
Tedder	10	2	20.8		2	14.3
Sulky rake	10	2	20.8	10	2	17.6

The data on hauling hay from the field and unloading it into the mow are not comparable for the two areas, and the figures afford no comparison of the efficiency of man labor for these operations. The western New York farmers were asked to give the number of tons that could be loaded, hauled to the barn or stack, and unloaded in a day by crews of different sizes, while the men of the Illinois area were asked for the time required to put on and take off a load with crews of different sizes. Bulletin 412 states, however, that the farmers in western New York "are on the average from 5 to 10 per cent more efficient in hauling in their hay than the average farmer of the country."

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 815

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

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CITRUS-FRUIT IMPROVEMENT: A STUDY OF BUD VARIATION IN THE LISBON LEMON.[1]

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IMPORTANCE OF THE LEMON INDUSTRY.

In the United States, the lemon (*Citrus limonia* Osbeck) is grown commercially practically only in California. According to the Thirteenth Census of the United States there were 957,000 lemon trees of bearing age in the United States in 1910, and 396,000 under bearing age, of which 941,293, and 379,676, respectively, were in California. The total production of all States in 1909 was reported in the Thirteenth Census as amounting to 2,770,313 boxes, of which California produced 2,756,221 boxes.

Additional information concerning the lemon industry of California will be found in United States Department of Agriculture Bulletin 813, entitled "Citrus-Fruit Improvement: A Study of Bud Variation in the Eureka Lemon."

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[1] This is the fifth in a series of bulletins summarizing the citrus-fruit improvement investigations of the Department of Agriculture. The four former reports, U. S. Dept. Agr. Buls. 623, 624, 697, and 813, presented the results of studies with the Washington Navel orange, the Valencia orange, the Marsh grapefruit, and the Eureka lemon, respectively.

The Eureka variety of lemon is the one most widely grown in California. The Lisbon variety is extensively grown in certain districts, particularly near the coast. During the last few years large plantings of Lisbon lemons have been made in certain districts.

During the early period of the commercial lemon industry in California the Villa Franca variety was planted in some sections, but at the present time its propagation has been almost abandoned.

HISTORY OF THE LISBON LEMON VARIETY.

The Lisbon lemon was introduced into California from Australia. Two different lots of trees of this variety were imported about the same time.

In 1872 Mr. Ellwood Cooper, a pioneer horticulturist of Santa Barbara, Calif., noticed that the imported lemons in the San Francisco markets were superior in appearance and quality to those raised from the seedling trees in southern California. He then conceived the idea of importing budded trees of some good foreign variety and planting them in California instead of seedlings. He discussed the matter with Mr. Samuel P. Stow, a neighbor, of Goleta, Santa Barbara County, Calif., and they decided to make an importation of the Lisbon variety, which they learned was cultivated in Australia. Accordingly, Mr. Stow purchased 12 budded trees in that country and had them shipped to San Francisco. These trees died in transit and a second shipment was ordered. The trees in the second lot arrived in good condition in 1874. Mr. Stow retained two of them and sent the remainder to Mr. Thomas A. Garey at Los Angeles, who propagated and distributed many trees of this variety. The Lisbon lemon trees in some of the coast plantings in California can be traced to the Cooper-Stow introduction.[1]

In 1875 a small shipment of trees and plants, including some small Lisbon lemon trees, was received from Australia by Judge J. W. North, of Riverside, Calif. These trees were turned over to Mr. D. H. Burnham, a nurseryman of Riverside, who planted them and distributed trees propagated from them under the name Lisbon.[2]

Many of the plantings of the Lisbon lemon variety in Riverside County, San Bernardino County, and other interior lemon districts of southern California can be traced to the North-Burnham introduction. Later, other importations of budded Lisbon trees were made by nurserymen and orchardists, so that the variety as now grown in California is made up of a number of separate introductions.[3]

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[1] Entire statement from interview with Mr. Ellwood Cooper, Hotel Lankershim, Los Angeles, Calif., June 19, 1917.

[2] Personal statement of Mrs. Mary M. Burnham, widow of Mr. D. H. Burnham, Riverside, Calif., May 29, 1917.

[3] Letter from Mr. R. C. Allen, Bonita, Calif., Apr. 2, 1917.

VARIABILITY WITHIN THE VARIETY.

The systematic studies of the variations of the California citrus varieties were begun with the Washington Navel orange in 1909. Later, investigations were commenced with the Marsh grapefruit and Valencia orange. In June, 1911, the study of variations within the Eureka lemon variety was begun. This variety was found to be subject to variability in about the same degree as the citrus varieties previously studied.[1]

One year after beginning the study of the Eureka lemon, tree-census studies were begun with the Lisbon variety. It was found that this variety was subject to variability in about the same degree as the Eureka. In order to secure definite information on this subject individual-tree performance records were begun on a plat of trees of the Lisbon variety in June, 1913, included in which were typical trees of all the important strains discovered up to that time. In these studies detailed performance records have been obtained covering a total of 128 Lisbon lemon trees. The individual trees in these plats have been picked monthly as far as possible. As with the Eureka lemon studies, the frequent pickings during a period of several consecutive years have resulted in the accumulation of a very large mass of data and information, from which conclusions have been drawn as to strain and individual-tree characteristics.

In addition to these detailed studies, cooperative individual-tree performance records have been carried on in several California lemon orchards during this period with about 13,000 trees of the Lisbon variety.

The variability of the Lisbon lemon described in the discussion of the results of these studies must be clearly distinguished from the fluctuating variability due to climatic, soil, cultural, or other environmental influences. The variations considered in these studies are those which have been found to be transmitted by budding and are inherent variations. The fluctuating variations, such as modification of the size of the fruits, slight differences in the color of the leaves or fruits, or similar changes due to climatic conditions, cultural factors, or other causes, have not been taken into account except as indicating the effect of certain environmental factors in tree and fruit development. All of the variations considered in these studies have been traced to individual fruit or limb variations in trees growing under normal conditions.

OBJECTS OF THE INVESTIGATIONS.

The objects of these investigations have been to determine the frequency and importance of bud variation in the Lisbon variety of lemon; to ascertain the relative value for commercial orcharding of the various strains originating from bud variations; to discover methods for isolating the best and eliminating the inferior strains through bud selection; to originate and introduce methods for replacing trees of inferior strains in established orchards through top-working or replanting; to introduce methods for securing reliable supplies of buds from superior performance-record trees for use by propagators; and to establish a system of individual-tree record keeping in commercial lemon orchards, in order to locate the desirable and undesirable trees.

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[1] See U. S. Dept. of Agriculture Bul. 813, entitled "Citrus-Fruit Improvement: A Study of Bud Variation in the Eureka Lemon."

PLAN OF THE INVESTIGATIONS.

These investigations have been carried on by means of individual-tree performance records, as in the case of the citrus varieties previously studied. The term "performance record" is used to mean a systematic record for a period of several years of the yield and behavior of individual trees. This record includes notes of the amount, the commercial quality, and the variability and other important characteristics of the fruits produced by the individual trees. In the case of lemon trees, individual performance records for at least two consecutive and normal seasons on trees which have reached a full bearing age are considered necessary in order to determine the value of the trees for commercial fruit production. Similar records for at least four years are advisable, in order to furnish the basis for the selection of superior trees as sources of bud wood for propagation.

The same general methods of picking, handling, assorting, weighing, counting, and classifying the fruits that were described in detail in United States Department of Agriculture Bulletin 813, entitled "Citrus-Fruit Improvement: A Study of Bud Variation in the Eureka Lemon," were followed in the studies of the Lisbon lemon.

The conditions considered essential in the location of the Lisbon individual-tree performance-record plats were the same as those which determined the final location of similar record plats of other varieties, namely, (1) the production of successful and profitable crops of fruit; (2) location on virgin land in order to avoid any influence of previous cultural treatment; (3) protection from cold, strong winds, or other climatic causes of tree and fruit injuries; (4) the absence of radical pruning, rebudding, top-working, or other similar tree treatments; (5) freedom from or the effective control of diseases and insect pests; (6) uniform irrigation and cultural practices during the entire history of the orchard; (7) reliable information concerning the history of the buds used in the propagation of the trees and the kind of stocks; (8) the prospect of settled ownership for a period of years; and (9) the absence of apparent local environmental factors influencing tree behavior, so that the results of the individual-tree studies would be truly comparative.

The original plat included 113 trees. Later additional trees which represented important strains were added to this number in order to secure as complete information as possible concerning variability within the variety.

METHODS OF KEEPING PERFORMANCE RECORDS.

The same general methods of keeping performance records as those governing the work with the Eureka lemon were followed in the studies of variations in the Lisbon variety. These methods involve considerably more detailed observation than is usually considered necessary in commercial orchard practices. A method which has been adopted for commercial lemon-tree record keeping is described in Farmers' Bulletin 794, entitled "Citrus-Fruit Improvement: How to Secure and Use Tree-Performance Records."

Each of the trees in the performance-record plat was given an individual-tree number which consisted of three parts: (1) The number of the block in which the tree occurred; (2) the number of the row in the block, counting from some fixed point; and (3) the number of the tree in the row. This number was painted in a vertical position on the tree trunk. The fruits from each tree were picked at monthly intervals. The size of the fruit to be picked was determined by means of metal rings similar to those used by the regular picking crew in the orchard. While the size of the rings varied at different seasons of the year, no change was ever made during any one picking, so that the crops from the individual trees each month were comparable with each other. The fruit from each tree was kept separate, and the lemons after picking were assorted into three grades, namely, Green, Tree-Ripe, and Culls. The Green grade was made up of the valuable commercial fruits and included both dark and light green lemons; the Tree-Ripe grade was made up of mature or prematurely ripened fruits, which usually were of small size and thin rinds; and the fruits of the Cull grade were frequently extremely coarse or malformed. In addition, all lemons which dropped to the ground between picking periods were included in the Cull grade. The number and weights of the lemons in each grade were secured, and all variable fruits were sorted out and classified. One lemon of each grade was taken from the crop of each tree at each picking and the number of seeds counted. In the event that any samples of fruits of any grade were missing, so that the seeds could not be counted, a note of this fact was made in the field form by using the words "No count."

All the data obtained in the field were recorded in special field note forms. As soon as practicable after each picking these data were transferred to forms which provided for a maximum of twelve pickings, or the monthly pickings for one year. When the complete record for an entire year had been obtained, it was transferred to a form having sufficient space for assembling the data of the individual tree for a period of several years. These performance-record forms, together with a more detailed account of the methods of compiling the records, are shown in United States Department of Agriculture Bulletin 813, entitled "Citrus-Fruit Improvement: A Study of Bud Variation in the Eureka Lemon."

DESCRIPTIONS OF THE IMPORTANT STRAINS.

LISBON STRAIN.

The Lisbon strain was originally called the Semidense Productive strain, on account of its habit of growth and productiveness. From the fact that the habit of growth of the trees and the characteristics of the fruits of this strain most nearly resemble the established ideal for the Lisbon variety, it has been decided to call it the Lisbon strain. The trees of this strain are more productive than those of any other strain of the variety. The bulk of the crop reaches the necessary size for picking during the winter and spring seasons.

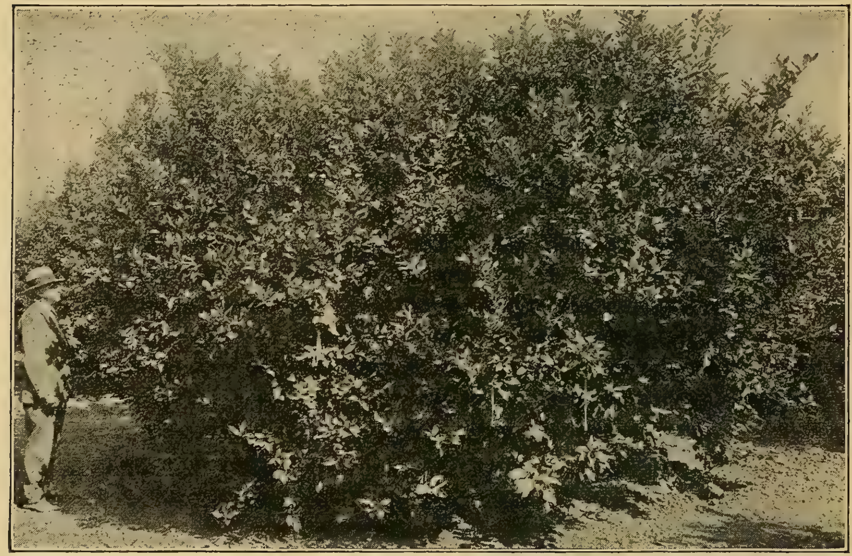


FIG. 1.—A typical lemon tree of the Lisbon strain (25 years old), No. 1-28-14 in the performance-record plat, showing the dense appearance of the foliage. The summarized record of this tree is presented in rank 23 in Table I.

The habit of growth of the trees is spreading, as shown in figure 1, and more or less upright. The fruits are largely borne on the inside of the tree and are protected from climatic injuries by the covering of rather dense dark-green leaves. The leaves are of medium size, oval in shape, obtuse, slightly crenate, abundant, and from deep to dark green in color. The flowers are usually perfect.

The typical fruits, as shown in Plate I, are oblong oval in shape, of medium size, and of very smooth texture. The rag is tender, and the juice is abundant and of strong acidity. The fruits average about four seeds each, and the rinds are thin.

In addition to the characteristics noted in the foregoing paragraphs, it seems evident that the trees of this strain are more inherently hardy than those of the other Lisbon strains. They are usually more thorny than the trees of the Open strain, but the thorns are usually not very large or dangerous to the fruits. For certain conditions of soil and climate, such as locations where the trees are subjected to strong winds at certain seasons of the year or to long periods of hot sunshine, it seems likely that the trees of the Lisbon strain are preferable to those of the Open strain on account of the protection afforded the fruits by the dense foliage and the resistance of the trees to unfavorable environmental conditions.

OPEN STRAIN.

The name of this strain was adopted because it describes the habit of growth of the trees, which is one of its most easily identified characteristics. The trees of the Open strain were more numerous than those of any other strain in the performance-record plat. In near-by orchards the proportion of trees of this strain was found to be much smaller than in the performance-record plats, and the leading strain was the Lisbon. In other Lisbon orchards in several important districts most of the trees in the orchards were found to belong to the Open strain. In certain districts the Lisbon strain is most commonly found, while in others the Open strain predominates.

It has seemed likely that the trees included in this strain really represent two rather distinct strains, the trees of one being very much more productive than the other. However, for the purposes of this study the two classes of trees have been brought together under one head and considered as belonging to one strain.

The trees produce fruits during all seasons of the year under normal conditions, resembling in this respect the trees of the Eureka strain of the Eureka lemon variety. As shown in figure 2, they have an open and somewhat drooping habit of growth. The leaves are of medium size, ovate in shape, obtuse, slightly crenate, rather few in number, and are of a deep-green color. The flowers are usually perfect.

The typical fruits, as illustrated in Plate II, are oval to oblong in shape and of medium size; the rinds are thin and of smooth texture; the rag is tender; and the juice is abundant and of strong acidity. The average number of seeds found in the fruits of this strain in the performance-record plats was five.

The importance of the Open strain lies in its tendency to fruitfulness during all seasons of the year under normal conditions. In this respect it is more desirable than the Lisbon strain. The trees have not been as productive as those of the Lisbon strain and have not shown as great resistance to unfavorable climatic conditions, such as low temperature or extreme heat, as the trees of the Lisbon strain. Therefore, it seems probable that the Open strain is better adapted to those sections where the climatic conditions are most moderate, as is the case in lemon districts near the coast. The Lisbon strain is probably best adapted to interior districts where extremes of heat and cold are more likely to occur.

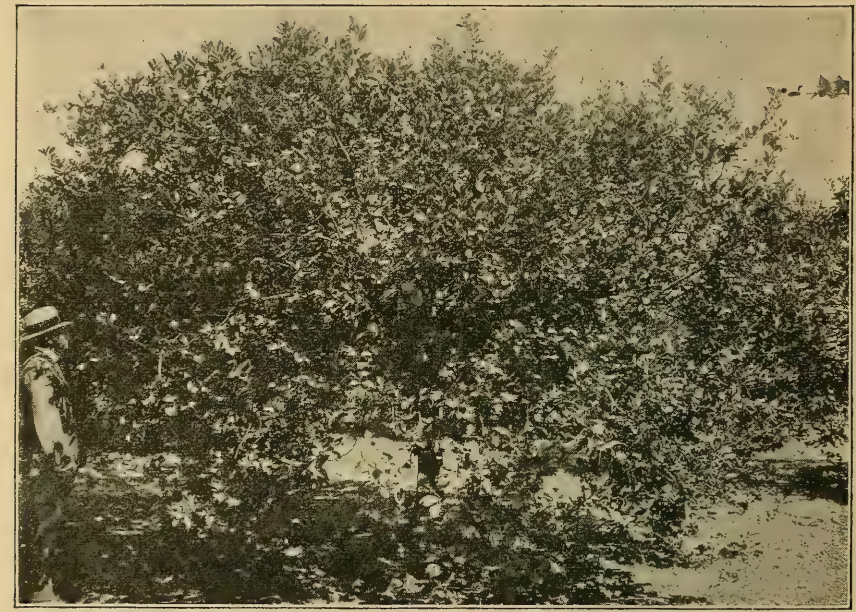
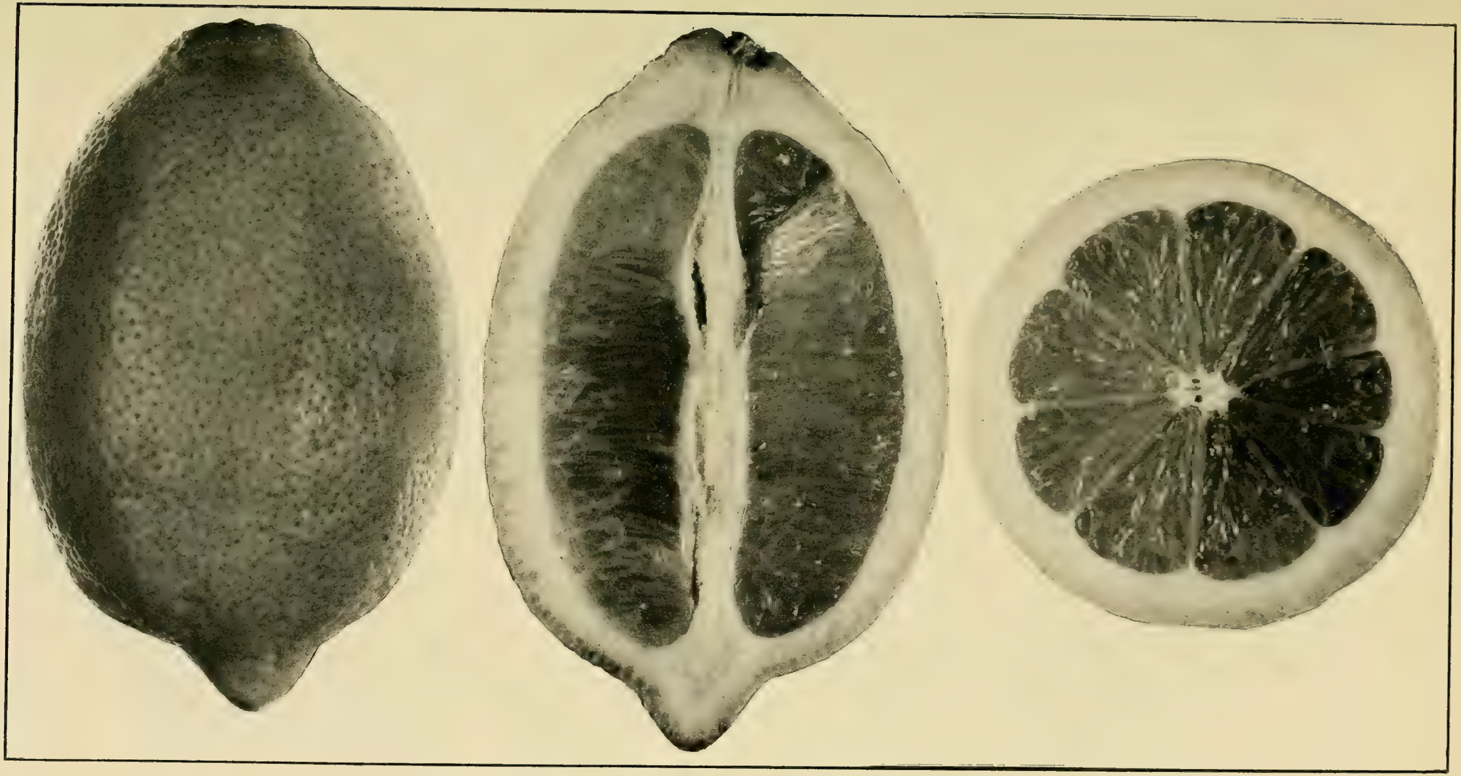


FIG. 2.—A typical lemon tree (25 years old) of the Open strain of the Lisbon variety, No. 1-34-11 in the performance-record plat, showing the open habit of growth characteristic of the trees of this strain. The summarized record of this tree is presented in rank 64 in Table I.

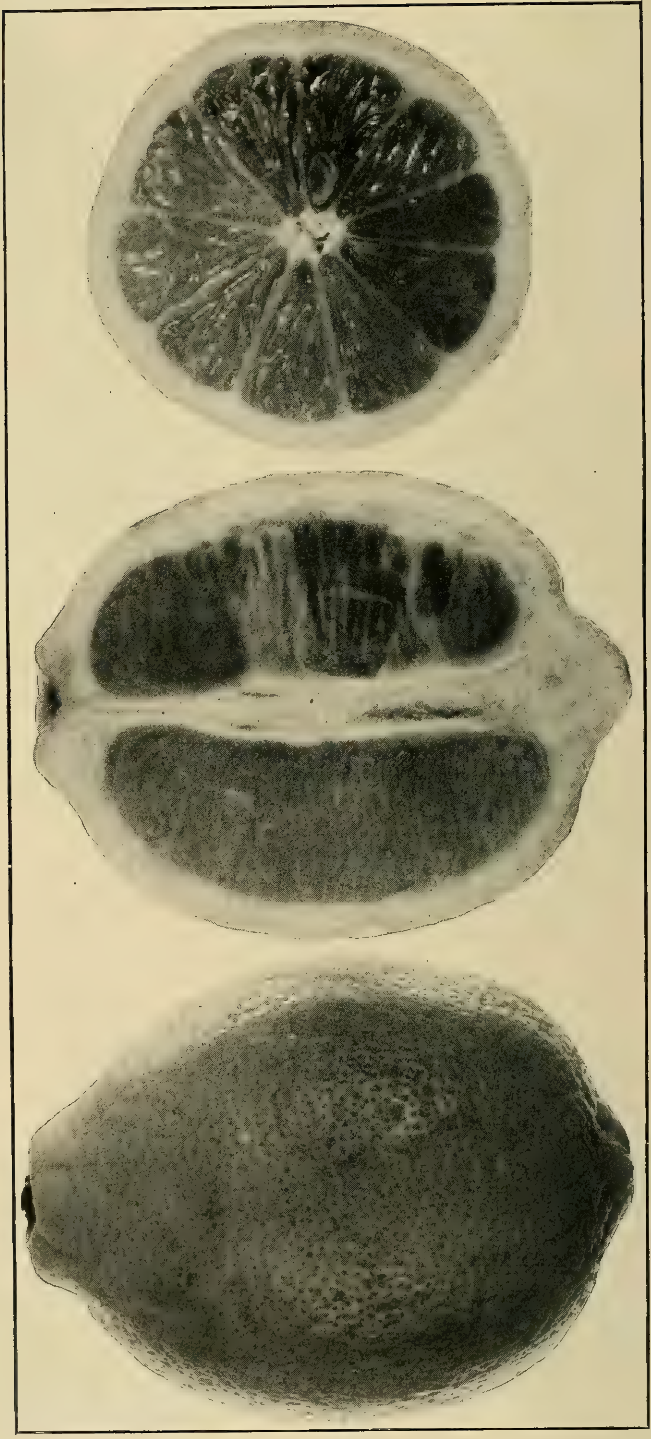
DENSE-UNPRODUCTIVE STRAIN.

The trees of the Dense-Unproductive strain show very vigorous vegetative growth. They bear large, pointed leaves and coarse fruits having thick rinds and a comparatively small quantity of juice. The proportion of trees of this strain in different Lisbon groves varies greatly. In some unproductive orchards most of the trees belong to this strain. The desirability of eliminating this strain in established orchards or in new propagations is emphasized not only from the standpoint of low production, but equally, if not more important, on account of the production of coarse, inferior fruits, which are likely to be very injurious to the reputation of California lemons.



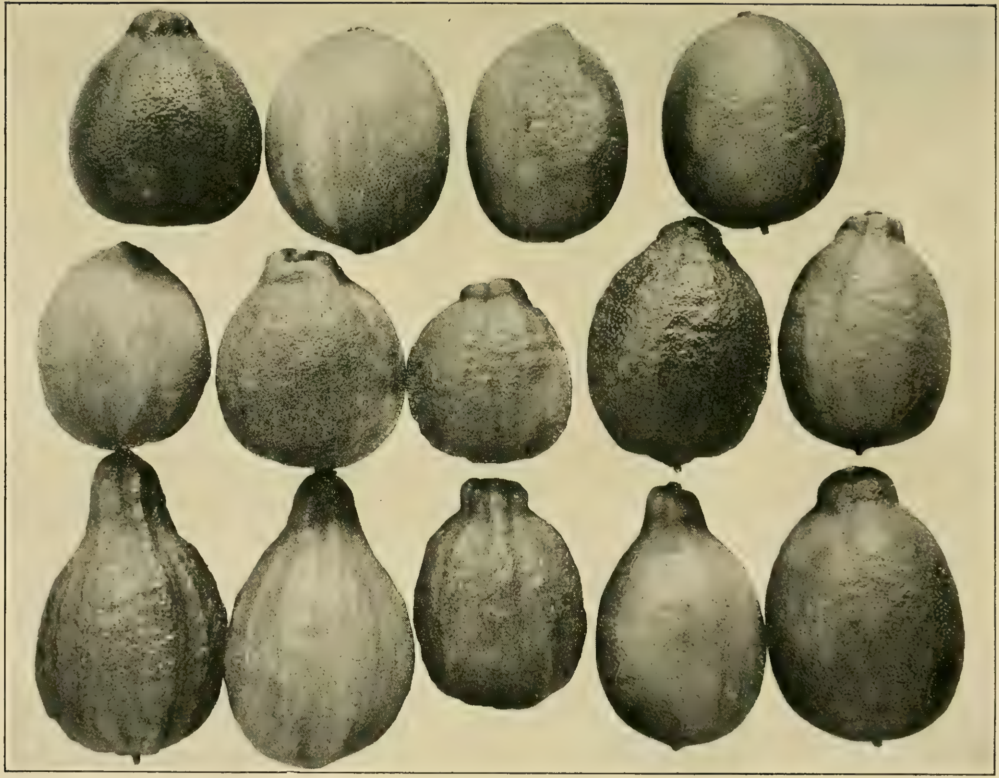
TYPICAL FRUITS OF THE LISBON STRAIN OF THE LISBON LEMON.

Natural size.



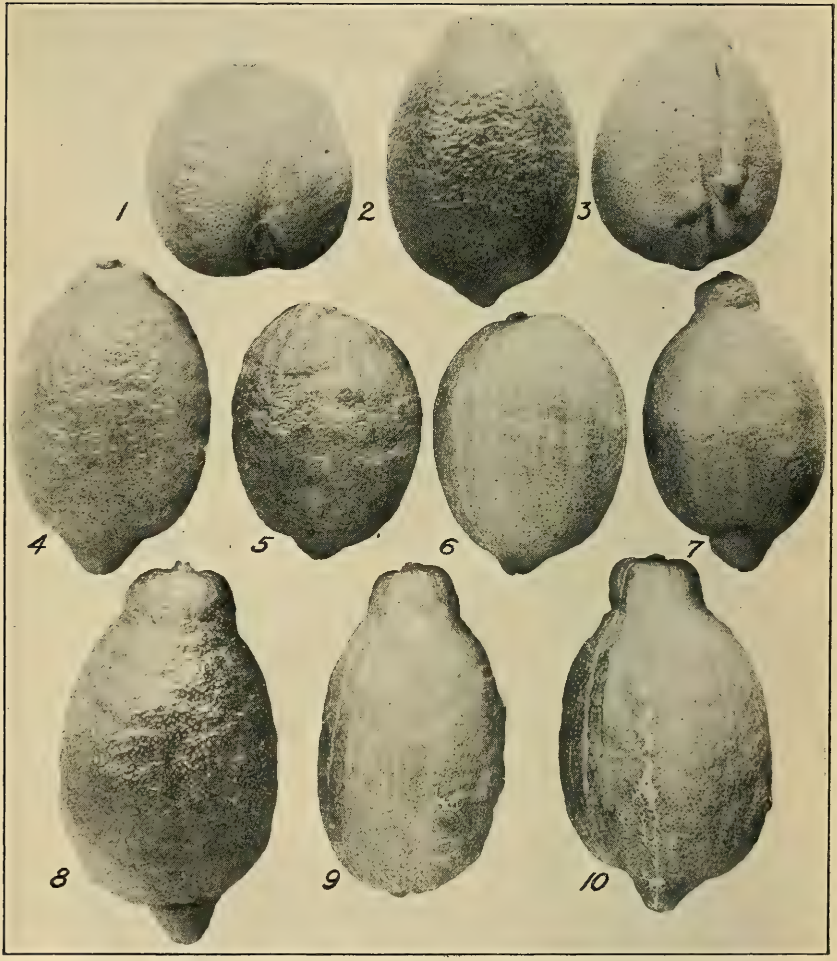
TYPICAL FRUITS OF THE OPEN STRAIN OF THE LISBON LEMON.

Nearly natural size. The fruit in center is 3¼ inches long.



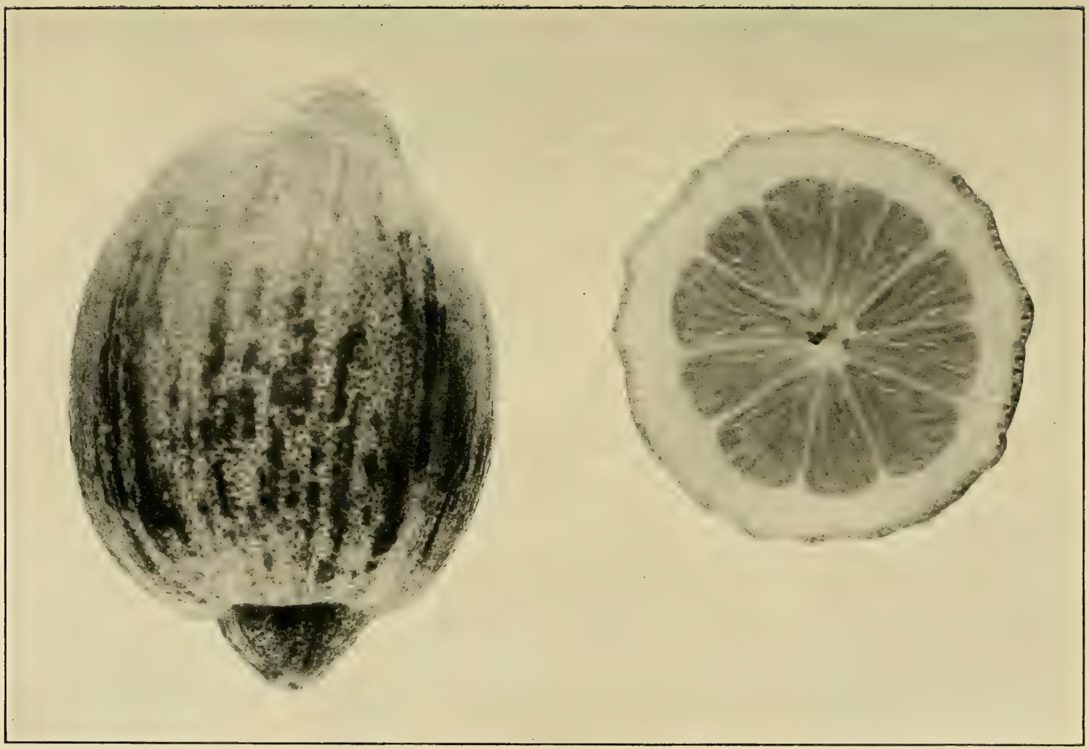
Typical Fruits from a Tree of the Dense-Unproductive Strain of the Lisbon Lemon.

The coarse texture and undesirable shapes of the fruits of this strain are clearly shown. Three-sevenths natural size. The natural size of the fruit at the right end of the center row is 3 inches long.



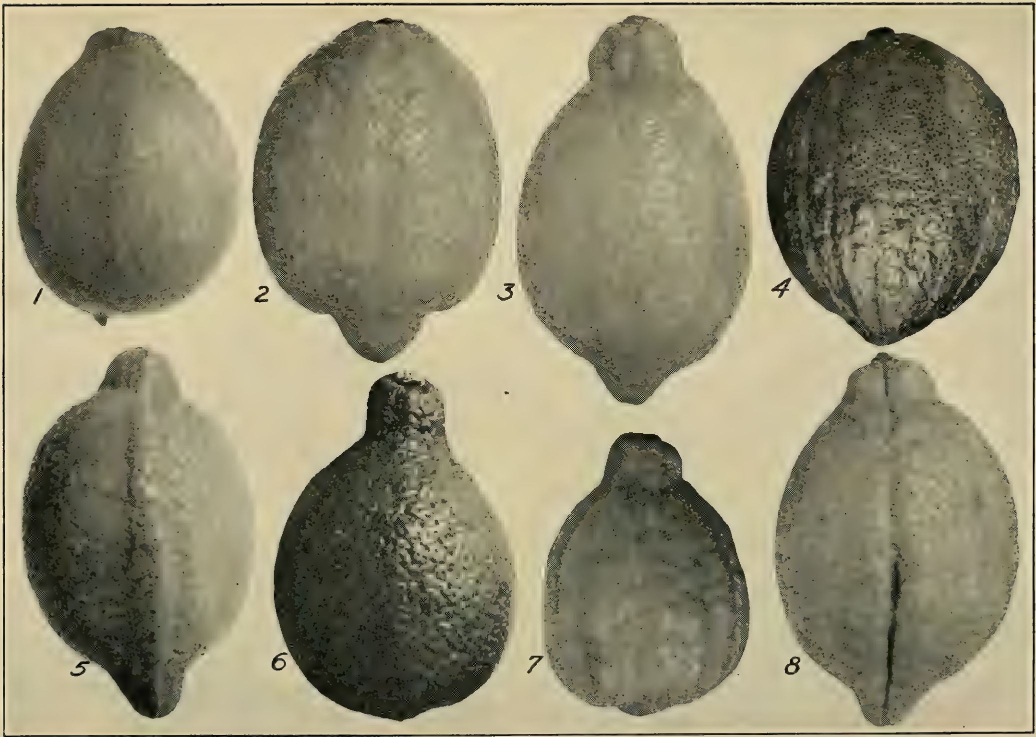
Typical Fruits from a Tree of the Bull Strain of the Lisbon Lemon.

Several variations and at least one mutation are shown: 1, Rounded, split end; 2, coarse, Lisbonlike; 3, creased; 4, Lisbonlike; 5, finely corrugated; 6, variegated; 7 and 8, normal Bull strain, collared and protruding; 9, collared and variegated; 10, collared, protruding and variegated. About three-sevenths natural size. The natural size of the fruit at the upper right hand is 3 inches long.



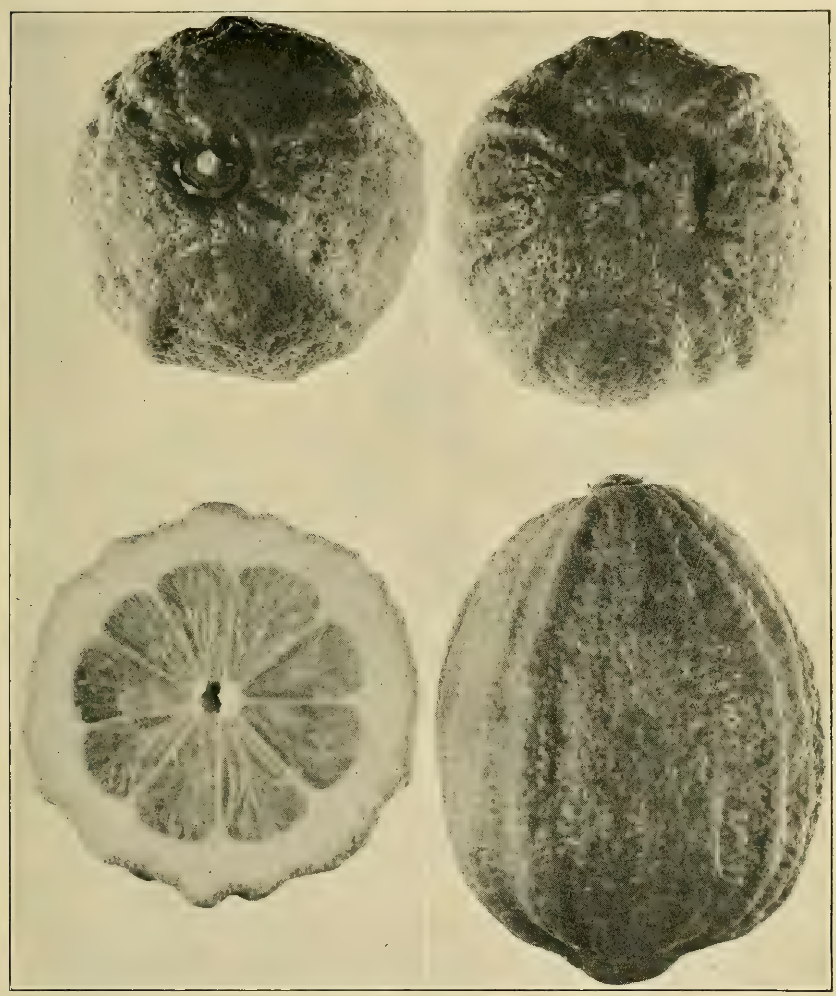
TYPICAL FRUITS OF THE VARIEGATED STRAIN OF THE LISBON VARIETY.

The fruits, leaves, and limbs of the trees of this strain are striped and the surface of the rind is slightly ridged. Natural size.



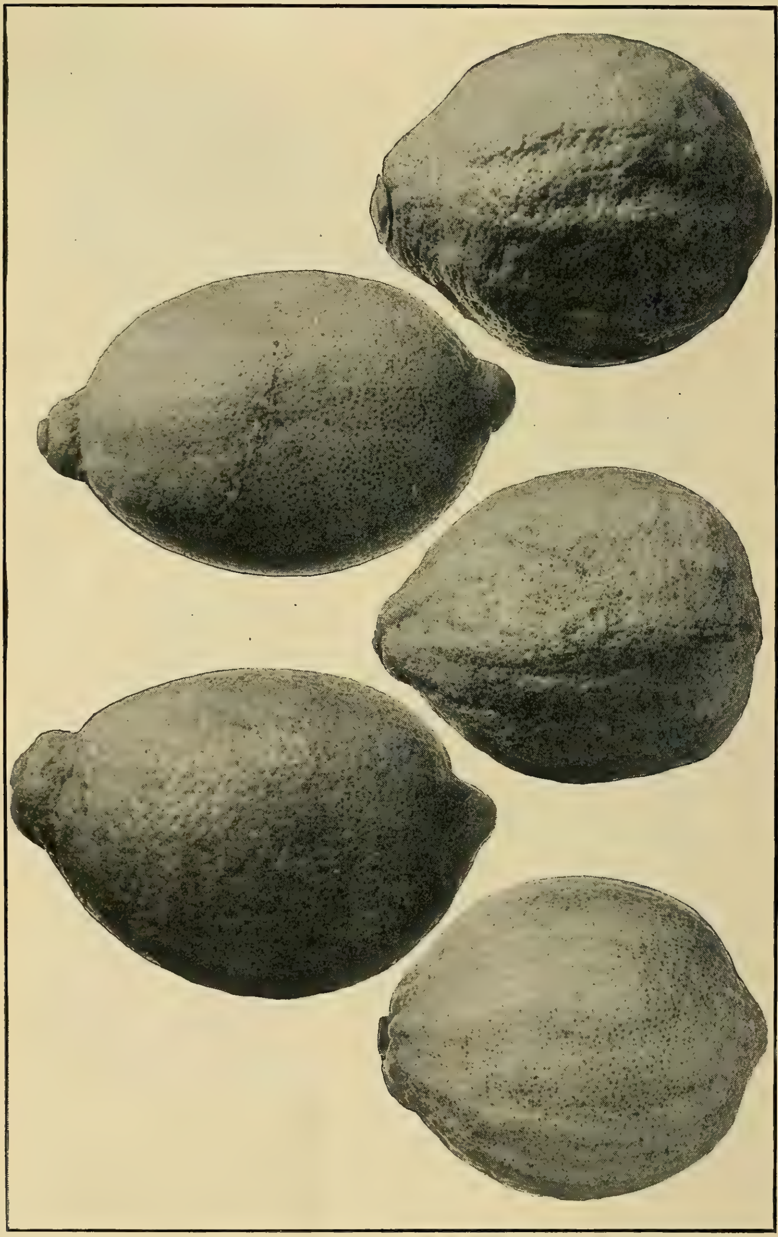
TYPICAL FRUITS FROM A TREE OF THE SPORTING STRAIN OF THE LISBON LEMON.

The variation in shape, texture, ridging, and development of stem and blossom ends are shown: 1, Slightly collared; 2, protruding blossom end; 3, collared; 4, uniformly creased; 5, raised ridge and collared; 6, bottle shape; 7, ridged and collared; 8, creased. Most of these fruits have little or no commercial value. About three-fifths natural size. The fruit at the upper left hand is 2¾ inches long.



TYPICAL FRUITS OF A CORRUGATED VARIATION FOUND ON A TREE OF THE OPEN STRAIN OF THE LISBON LEMON.

This variation has been frequently found as individual fruit, limb, and entire tree bud sports. The fruits are commercially worthless, but are interesting as throwing light on the origin of lemon strains from bud variations. Nearly natural size. The fruit at the lower right hand is 2⅞ inches long.



Two Variations Found on Separate Branches of a Lemon Tree on which all the Other Fruits Were of the Lisbon Strain.

About four-fifths natural size. The fruit at the upper right hand is 3¼ inches long.

The trees bear low yields of inferior crops, mostly during the late-fall and early-winter seasons. They have a spreading habit of growth and attain great size unless pruned vigorously. They develop a large number of vigorous-growing, upright, vegetative branches, or suckers.

The leaves are large and sharply pointed. They develop abundantly, making dense-appearing trees, and their normal color is deep green. The flowers are often imperfect, the pistil being small or rudimentary. The pollen is frequently scant and of low vitality. The thorns are abundant and often very large, long, and sharply pointed and have been found to be responsible for injuries to the fruits which in many cases lead to decay and loss to the growers.

The fruits, as shown in Plate III, are somewhat oblong, usually collared, and blunt or flattened at the blossom end. The rinds are thick, coarse, and rough in texture and are more or less ridged. The rag is tough and abundant, and the juice is scant and of low acidity and poor quality. The seeds average between one and two to a fruit.

The reputation for extreme thorniness of the Lisbon variety in most cases is due to the many thorns developed by the trees of this strain. It also seems likely that the decay sometimes observed in Lisbon lemons is due to the thorn injuries to the fruits borne by the trees of this and the Bull strain. This condition serves to emphasize the desirability of eliminating these strains and planting only trees of the Lisbon or Open strain, which have relatively few thorns.

BULL STRAIN.

The name of this strain was adopted because the word Bull is in common use among Lisbon lemon growers for certain rank-growing undesirable trees. These trees show very vigorous vegetative growth and have large, sharply pointed, light-green leaves. They produce coarse fruits with thick rinds and little juice, which is of poor quality. This strain is one which should be eliminated in all established orchards. It should not be propagated for any commercial purpose. In many established orchards many trees of the Bull strain have been recently top-worked successfully with buds from carefully selected trees of the Lisbon or Open strains. A very noticeable improvement in the commercial grade of fruit has followed the elimination of the trees of the Bull strain in those orchards.

The trees bear comparatively heavy crops during the winter. They have a spreading habit of growth and unless restrained by heavy pruning attain great size. They develop many large upright-growing suckers formerly highly prized as bud wood for propagation. The pointed leaves are large and very abundant, so as to make dense-appearing trees, and their color is usually light green. The thorns are large and abundant and are frequently very long and sharply pointed. They are responsible for many injuries to the fruit, particularly during periods of strong winds.

The typical fruits, as shown in Plate IV, are oblong in shape and likely to be ridged or malformed. The rinds are usually very thick, and coarse and rough in texture; the rag is abundant and tough; the juice is scant and lacks acidity and flavor. The fruits, which have an average of about four seeds, grow very rapidly, and when picked with the normal interval between pickings are much larger than those of other strains.

The comparatively heavy production of the trees of the Bull strain has made some growers hesitate to eliminate them. The fruits are poor, and when included in the regular pack frequently depreciate the value of the crops in which they occur. From the observations on the value of trees of the Bull strain and their fruits, it can be safely recommended that all such trees be top-worked or replaced with trees of the desirable strains.

VARIEGATED STRAIN.

Other strains of the Lisbon variety than those described in this bulletin have been observed but have not been studied fully as yet. Among these additional variations the Variegated strain is particularly interesting, occurring rather frequently in some Lisbon orchards. A typical example of a fruit of the Variegated strain is shown in Plate V. The trees and fruits are similar in appearance and have very much the same characteristics as those of the Variegated strain of the Eureka variety.

SPORTING STRAIN.

The trees of the Sporting strain of the Lisbon variety resemble in their condition of variability the Sporting trees of the Eureka variety. They contain branches bearing fruits typical of all the strains so far observed in the Lisbon variety, together with other variations not classified as strains in these studies. One of the most common of these minor variations found in the trees of the Sporting strain is a bell-shaped fruit, usually deeply ribbed or fluted in appearance. This variation is shown in Plate VI, figure 7. This and the other forms shown in the same illustration were found on a lemon tree grown from a single bud. Other variations of frequent occurrence are uniformly ridged fruits. This condition gives the fruits the appearance of fine corrugations, as shown in Plate VII. Entire trees bearing both the bell-shaped ribbed fruits and the corrugated-appearing fruits have been observed in the orchards in which the performance records have been obtained. In the trees in the performance-record plats, however, only single fruit or branch variations having these characteristics have been found.

The trees of the Sporting strain vary in size, habit of growth, and productiveness according to the character of the variations borne by them.

LESSONS TAUGHT BY THESE INVESTIGATIONS.

As in the case of the other lemon variety, the performance-record studies of the Lisbon trees have been particularly interesting, for the reason that the frequent pickings have made possible the almost continuous systematic observation of individual-tree behavior throughout the entire year. A very large number of buds taken from superior trees of both the Lisbon and Open strains in the performance-record plats have been furnished to propagators. These buds from individual parent trees have been kept separate, so that each progeny can be traced back at any time from the orchard planting to the parent trees. In addition to these buds which have been cut from the best of performance-record trees, buds have also been taken from the poorest trees, in order to compare under orchard conditions the behavior of the progenies of the most desirable with those from the undesirable parent trees.

The early fruiting of the young trees propagated from select parent trees is just as marked in the Lisbon as in the Eureka variety; in fact, it is even more striking in the Lisbon variety, as it was formerly thought that trees of the Lisbon strain were slow in coming into production. Experimental propagations from productive parent trees of this strain in the performance-record plat have shown that young trees of this strain come into fruiting very early. Within some of the strains marked variations of importance commercially were found, but none as striking as the variations which distinguish the strains themselves. These individual-tree differences within the strains should be taken into account by the performance-record keeper and the knowledge of these variations utilized in the selection of trees for top-working or for use as sources of bud wood.

There is a marked correlation between the quantity and quality of the fruits produced by the individual trees of the different strains in the Lisbon variety. A similar correlation was found in the studies of the individual-tree production of the various strains of the Eureka lemon, the Washington Navel orange, the Valencia orange, and the Marsh grapefruit. The trees bearing the most lemons usually produce the best commercial fruits. Usually the most productive trees show the fewest marked variations in fruits from the type of the strain to which they belong. This condition makes the securing of production records especially valuable, in that it enables the grower to secure a reliable conception of the fruits of the individual trees.

PRESENTATION OF DATA.

The diagrams and tables presented herewith in summarizing the studies on the Lisbon lemon variety have been prepared from individual-tree performance records of 128 trees located in a 100-acre orchard near Corona, Calif., which was planted in 1893. Only a few crops of winter barley had been grown on the property prior to that time. Records were begun on 113 of these trees in July, 1913. Two months later, one of the trees adjoining this block was found to be of the Sporting strain, and it was included in the record plat. Because of the small crops borne by the tree at that season, its record for that year has been summarized as though the 12 months were represented. An additional block of 14 trees, among them being several representatives of the Bull strain, was added to the plat in July, 1914.

The orchard where these trees were located was protected by orchard heaters from the frosts of the winter of 1912-13, and very little injury occurred to the trees or fruit. The excessive number of fruits of the Cull grade recorded in October, 1913, and to some extent in December, were put in that grade because they showed slight injury from the frosts of the previous winter. Performance records were secured on the Lisbon plat continuously from the time of its establishment until June, 1917, inclusive, a 4-year period for the 114 trees first selected and a 3-year period for the remaining 14 trees. Seven trees of the Open strain near the center of the original plat became badly diseased in 1915 and were given a severe pruning and other treatment to restore them to normal production. On this account these trees have been omitted in summarizing the records presented herewith.

Included in the 121 trees for which records are presented are representatives of the five Lisbon strains, as follows: Lisbon, 22; Open, 77; Bull, 11; Dense Unproductive, 8; and Sporting, 3.

The average annual crop of each of the 121 trees in the investigational plat of Lisbon lemons is shown in Table I, which also shows the percentage (by weight) of green fruits produced, the percentage (by number) of variable fruits, and the average number of seeds per fruit for each of the trees. The trees are listed in this table in the order of their average annual production by weight. The trees of the Bull strain are large and vigorous growing and produce heavy crops, but their fruit is coarse, thick skinned, and much less desirable than that borne by the trees of the Lisbon strain. The trees of the Sporting strain may bear heavy or light crops, but because of the variable character of the fruit those trees are very undesirable, from the standpoint of both the producer and the propagator. It is interesting to note that Table I shows that 18 of the 22 trees of the Lisbon strain occurring in this plat averaged heavier crops than any other trees except some of those of the Bull and Sporting strains.

TABLE I.—*Summarized statement of the average annual production of 121 individual lemon trees of the Lisbon variety for which detailed performance records were obtained for the 4-year period from July, 1913, to June, 1917, inclusive.*

[Detailed performance records of the trees marked with an asterisk (*) are shown in Table II. The trees marked with a dagger (†) were added to the plat in July, 1914; hence the data shown for them are based on records for the 3-year period from July, 1914, to June, 1917, inclusive. Records of the number of seeds per fruit cover the 3-year period from July, 1914, to June, 1917, inclusive.]

Rank.	Strain.	Tree designation.	Average annual crop production.				Seeds per fruit.
			Weight.	Number.	Green grade.	Variable fruits.	
			Pounds.		*Per cent.*	*Per cent.*	
1	Lisbon	*1-27-10	736.47	2,897.00	80.5	36.7	4.36
2	do	1-27-11	708.63	2,788.25	79.6	37.4	5.42
3	do	1-26-11	700.70	2,668.00	84.0	41.9	4.56
4	do	1-28- 8	700.19	2,701.50	84.0	38.7	5.34
5	Bull	*†1-56-15	694.65	2,527.67	89.6	43.3	5.05
6	Lisbon	*1-26- 8	690.80	2,586.25	86.6	39.2	4.06
7	Bull	†1-56-12	678.75	2,459.33	89.4	56.3	4.44
8	Lisbon	1-28-10	676.28	2,596.00	84.4	39.2	4.69
9	Bull	†1-57-17	669.08	2,465.00	88.8	51.7	4.65
10	do	*†1-56-14	665.92	2,451.33	90.1	42.7	4.08
11	Lisbon	1-35- 9	665.63	2,742.75	64.3	19.4	6.77
12	do	1-27-16	657.73	2,530.50	85.3	33.4	4.63
13	do	*1-27- 9	657.06	2,600.00	79.1	36.2	5.32
14	do	1-27-14	656.73	2,475.00	87.2	34.9	5.87
15	do	1-26-17	655.08	2,553.25	82.4	31.7	5.51
16	do	1-27-17	654.55	2,494.50	86.8	37.4	1.43
17	do	*1-29-17	644.41	2,463.00	87.6	39.3	2.14
18	do	1-29-16	641.44	2,454.00	88.1	41.2	1.70
19	Bull	†1-56-17	640.44	2,345.33	90.2	48.6	3.85
20	do	†1-57-14	640.17	2,373.33	90.9	47.9	4.21
21	Lisbon	1-26-16	634.88	2,445.75	86.4	40.8	3.76
22	Sporting	*1-25-10	619.48	2,374.50	83.9	50.6	3.38
23	Lisbon	1-23-14	615.73	2,345.25	84.9	35.4	4.24
24	Bull	*†1-57-16	614.52	2,264.67	87.7	44.9	5.20
25	do	†1-56-13	608.81	2,195.67	91.9	41.5	4.63
26	Lisbon	*1-28-17	604.84	2,292.50	87.4	32.8	2.13
27	Bull	†1-57-13	603.23	2,201.00	90.3	43.9	4.38
28	Lisbon	1-35-14	593.38	2,520.25	63.8	16.2	8.20
29	Open	*1-32-10	590.20	2,370.25	72.0	19.9	4.65
30	do	1-29-15	588.69	2,360.75	73.0	24.0	4.56
31	Lisbon	1-23-16	587.88	2,261.50	88.0	37.4	1.82
32	Bull	†1-57-11	586.33	2,134.67	91.2	50.1	2.98
33	Open	1-31-11	581.47	2,405.00	71.2	21.0	4.50
34	do	1-31-17	579.72	2,443.25	63.1	19.5	4.82
35	do	1-29-13	577.36	2,339.50	71.0	21.6	4.57
36	do	1-32-11	575.30	2,344.00	69.6	17.9	5.34
37	do	1-31- 8	570.52	2,286.00	72.3	21.6	4.87
38	do	1-33- 8	566.95	2,293.50	67.9	20.4	5.53
39	do	*1-29-14	554.88	2,244.25	70.9	22.2	5.25
40	do	1-26-13	551.48	2,204.50	75.3	22.3	4.70
41	Sporting	†1-56-11	551.19	2,011.00	90.5	42.3	2.75
42	Open	1-26-10	550.08	2,223.50	72.4	23.9	4.14
43	Lisbon	1-26-18	549.23	2,181.25	78.0	30.3	6.10
44	Open	1-31-18	542.83	2,266.25	66.2	20.6	4.11
45	do	1-33-18	539.61	2,290.25	64.4	19.3	5.43
46	Lisbon	1-27-15	538.80	2,114.50	78.8	32.4	3.98
47	Open	1-33- 9	536.91	2,257.50	64.3	15.9	5.54
48	do	1-34- 9	536.31	2,217.50	64.2	16.9	5.18
49	do	1-32- 9	536.00	2,244.25	67.2	18.0	5.41
50	do	*1-33-17	533.88	2,242.25	66.9	19.5	4.94
51	do	1-32- 8	533.84	2,140.00	72.2	21.3	4.40
52	do	1-33-14	531.34	2,184.50	67.8	24.6	5.37
53	do	1-32-18	528.38	2,225.25	62.9	15.9	5.00
54	do	1-31-16	527.42	2,228.75	64.0	15.8	5.21
55	do	1-31-10	526.36	2,158.00	70.1	18.9	4.49
56	do	1-26- 9	526.27	2,156.75	68.3	21.8	4.30
57	Bull	*†1-57-12	524.85	1,967.67	86.5	48.0	3.15
58	Open	1-32-16	523.27	2,259.25	61.2	14.7	5.35
59	do	*1-29-10	522.48	2,102.25	70.1	21.6	4.33
60	do	1-31- 9	522.22	2,128.25	71.4	21.8	5.21
61	do	1-34-18	517.41	2,171.25	61.8	15.6	4.98
62	do	1-34-13	516.84	2,234.75	56.6	13.0	5.09
63	do	1-31-12	515.92	2,137.25	67.6	17.9	4.91
64	do	1-34-11	515.36	2,237.00	59.4	14.8	5.74
65	do	1-33-11	506.86	2,102.25	63.1	19.5	4.82
66	do	1-30- 8	502.98	2,033.50	65.8	19.4	4.27
67	do	*1-33-10	502.45	2,114.00	62.3	16.1	4.60

TABLE I.—*Summarized statement of the average annual production of 121 individual lemon trees of the Lisbon variety for which detailed performance records were obtained for the 4-year period from July, 1913, to June, 1917, inclusive*—Continued.

[Detailed performance records of the trees marked with an asterisk (*) are shown in Table II. The trees marked with a dagger (†) were added to the plat in July, 1914; hence the data shown for them are based on records for the 3-year period from July, 1914, to June, 1917, inclusive. Records of the number of seeds per fruit cover the 3-year period from July, 1914, to June, 1917, inclusive.]

Rank.	Strain.	Tree designation.	Average annual crop production.				Seeds per fruit.
			Weight.	Number.	Green grade.	Variable fruits.	
			Pounds.		*Per cent.*	*Per cent.*	
68	Open	1-30-15	501.28	2,121.25	63.0	13.6	5.07
69	do	1-34- 8	500.69	2,114.00	63.2	15.4	5.18
70	do	1-30-13	497.14	2,049.25	68.0	23.4	4.15
71	do	1-26-14	496.86	2,013.75	70.2	19.9	5.03
72	do	1-27-12	496.64	2,052.50	68.8	13.7	4.58
73	do	1-33-12	493.63	2,061.75	64.5	19.5	4.96
74	do	1-26-12	492.67	1,997.25	74.6	20.7	4.84
75	do	*1-30-11	480.17	2,022.50	66.7	17.2	4.71
76	Lisbon	*1-27- 8	479.33	1,914.75	73.1	20.2	4.58
77	Open	1-34-10	475.09	1,976.00	64.1	18.3	5.54
78	do	1-35-11	474.38	2,084.50	52.6	10.0	6.31
79	do	1-34-16	472.19	2,043.00	57.7	15.0	5.21
80	do	1-34-15	466.09	2,159.25	52.1	14.4	4.93
81	Sporting	*1-83-10	462.52	1,712.75	85.6	47.7	3.03
82	Open	1-32-17	461.97	1,962.25	59.7	13.5	5.12
83	do	1-30-17	459.39	1,923.50	64.2	20.4	5.07
84	do	1-30-14	459.28	1,967.50	60.9	21.9	5.04
85	do	*1-30-10	457.78	1,930.50	68.4	25.6	4.74
86	do	1-28-15	455.20	1,913.50	68.7	22.8	4.45
87	do	1-30-16	453.48	1,908.25	63.0	20.2	4.93
88	do	1-27-13	450.83	1,856.25	69.6	21.6	5.05
89	do	1-30-18	447.53	1,892.25	63.9	20.4	4.26
90	do	1-34-17	443.52	1,911.50	58.9	18.6	5.06
91	do	1-28-12	441.86	1,851.50	66.4	22.5	4.63
92	do	1-33-13	437.95	1,877.00	62.2	19.7	5.38
93	do	*1-34-12	437.08	1,877.25	58.5	18.8	5.09
94	do	1-28-18	436.19	1,836.50	65.1	20.0	5.17
95	do	1-26-15	428.78	1,805.00	67.1	20.7	5.11
96	do	1-34-14	425.84	1,820.00	59.0	16.3	5.05
97	do	1-29-18	424.72	1,777.00	66.5	24.8	4.57
98	do	1-28-11	424.42	1,788.75	67.3	19.6	4.54
99	do	1-28-13	410.09	1,757.00	67.8	17.8	4.41
100	do	1-35-17	405.69	1,813.75	50.5	10.2	5.90
101	do	*1-35-12	398.53	1,814.00	43.4	9.6	6.82
102	do	1-28- 9	395.94	1,703.50	64.6	22.5	4.79
103	do	†1-56-16	386.79	1,584.00	61.8	32.2	5.11
104	do	1-27-18	383.73	1,687.50	63.4	21.7	4.81
105	do	1-33-15	383.05	1,647.00	60.4	20.5	5.43
106	do	1-35-13	382.64	1,738.25	46.0	12.0	6.77
107	do	1-35-16	377.81	1,692.00	49.2	9.4	6.23
108	do	†1-57-15	376.35	1,526.00	65.9	33.7	5.30
109	do	1-35-18	369.55	1,613.25	51.8	11.5	6.22
110	do	1-35-10	362.97	1,564.00	54.9	16.2	6.10
111	do	1-35- 8	350.38	1,566.75	49.0	8.9	6.46
112	do	1-33-16	344.64	1,464.25	61.1	19.5	4.39
113	do	*1-35-15	336.78	1,531.00	45.9	11.3	6.67
114	Dense Unproductive	*1-29-11	281.81	1,050.25	92.2	70.4	1.38
115	do	1-30- 7	231.14	876.00	89.5	73.9	1.44
116	do	1-29- 8	223.36	853.00	91.8	71.3	2.05
117	do	*1-29-12	217.58	834.00	90.4	73.4	1.55
118	do	1-29- 7	212.56	793.50	94.2	71.5	1.74
119	do	1-29- 9	204.22	789.50	89.7	75.1	1.03
120	do	1-30- 9	195.61	757.75	88.7	73.4	1.25
121	do	*1-30-12	159.75	628.75	85.8	68.9	2.29

Figure 3 shows graphically the variations of the average annual crops of the individual Lisbon trees, showing the total crops and the proportions of fruit of the Green, Tree-Ripe, and Cull grades for each tree. The trees are listed from left to right in the same order as in Table I.

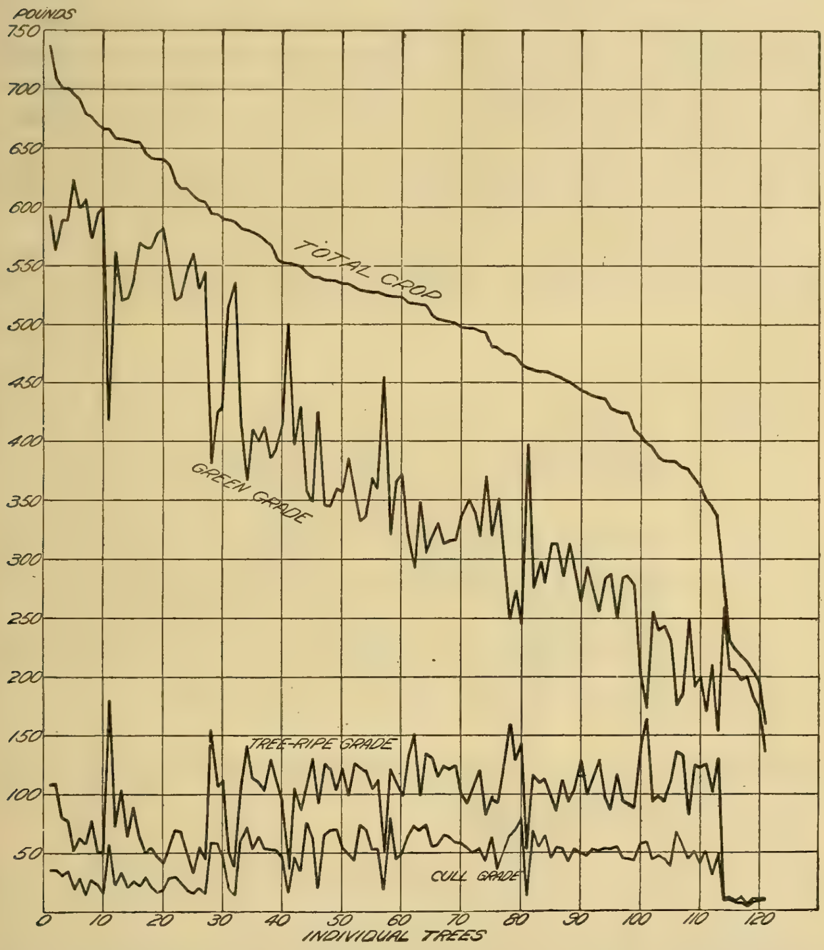


FIG. 3.—Diagram showing the average annual total crop of Lisbon lemons and the production by the three commercial grades from the individual trees in the investigational performance-record plat during the 4-year period from July, 1913, to June, 1917, inclusive. The data for 14 trees, as noted in Table I, cover only the 3-year period from July, 1914, to June, 1917, inclusive.

Table II shows the relative positions of the individual trees in the Lisbon investigational plat. The strain to which each tree belongs is indicated and its rank by production as listed in Table I. This illustrates the distribution in the plat of the trees of the different ranks and strains.

In Tables III and IV are presented the detailed performance records of 25 representative trees from the Lisbon investigational plat, including examples of all the strains. These trees were arbitrarily selected by taking every fourth tree of the Lisbon strain, as listed in Table I, every eighth tree of the Open strain, every third tree of the Bull and Dense-Unproductive strains, and two of the three trees of the Sporting strain, always including the highest and lowest ranking trees of each strain. In this way the selection included 6 trees of the Lisbon strain, 10 of the Open strain, 4 of the Bull strain, 3 of the Dense-Unproductive strain, and 2 of the Sporting strain.

TABLE II.—*Distribution of lemon trees of the Lisbon variety in the investigational performance-record plat, showing also the strain and the rank in crop production of each individual tree for the 4-year period from July, 1913, to June, 1917, inclusive.*

[The positions of trees in ranks 22 and 81 are not indicated in the table. They were both No. 10 in rows 25 and 83, respectively, both belonging to the Sporting strain. The tree numbers count from the southern end, which is taken as the head of the row. Explanation of symbols: ⊙= Lisbon strain, □= Bull strain, ●= Open strain, △= Dense-Unproductive strain, ⊡=Sporting strain, ×=not included in records.]

Serial No. of the tree in the row.	Number of row																							
	35		34		33		32		31		30		29		28		27		26		56		57	
	Strain.	Rank.	Strain.	Rank.	Strain.	Rank.	Strain.	Rank.	Strain.	Rank.	Strain.	Rank.	Strain.	Rank.	Strain.	Rank.	Strain.	Rank.	Strain.	Rank.	Strain.	Rank.	Strain.	Rank.
7	...	...	...	...	...	...	...	...	...	...	△	115	△	118	...	...	...	...	...	...	...	...	...	...
8	●	111	●	69	●	38	●	51	●	37	●	66	△	116	⊙	4	⊙	76	⊙	6	...	...	...	...
9	⊙	11	●	48	●	47	●	49	●	60	△	120	△	119	●	102	⊙	13	●	56	...	...	...	...
10	●	110	●	77	●	67	●	29	●	55	●	85	●	59	⊙	8	⊙	1	●	42	...	...	...	...
11	●	78	●	64	●	65	●	36	●	33	●	75	△	114	●	98	⊙	2	⊙	3	⊡	41	□	32
12	●	101	●	93	●	73	×	...	●	63	△	121	△	117	●	91	●	72	●	74	□	7	□	57
13	●	106	●	62	●	92	×	...	×	...	●	70	●	35	●	99	●	88	●	40	□	25	□	27
14	⊙	28	●	96	●	52	×	...	×	...	●	84	●	39	⊙	23	⊙	14	●	71	□	10	□	20
15	●	113	●	80	●	105	×	...	×	...	●	68	●	30	●	86	⊙	46	●	95	□	5	●	108
16	●	107	●	79	●	112	●	58	●	54	●	87	⊙	18	⊙	31	⊙	12	⊙	21	●	103	□	24
17	●	100	●	90	●	50	●	82	●	34	●	83	⊙	17	⊙	26	⊙	16	⊙	15	□	19	□	9
18	●	109	●	61	●	45	●	53	●	44	●	89	●	97	●	94	●	104	⊙	43	...	...	...	...

The following notes regarding some of the methods of recording and compiling the data presented in Table III may assist the reader to understand and interpret it.

Commercial performance records were not being obtained on the orchard in which this plat was located, and the workmen were unacquainted with such operations. Consequently on a few occasions the fruit from some of the performance-record trees was removed by the regular workers in the grove before the records were made. Fortunately the most of such losses occurred in the summer or fall when the production was light and the total recorded crops were not greatly affected thereby, but the record for tree 1–83–10 is considerably reduced by similar losses in January and February, 1914, at which time the production was very heavy. At least 200 pounds of fruit was picked at that time and not recorded, so that the relative rank for this tree is really considerably higher than is shown in the accompanying data. All instances in which fruit was lost, as described above, are noted in Table III.

Table IV shows the different forms of most frequent occurrence which were classed as variable fruits, and the total number of each form recorded from each of the trees listed in Table III during the investigational period. It will be noted that the large number of fruits of the Lisbon strain listed as collared, protruding blossom end, and ridged vary but slightly from the typical fruit of the variety and are continuous variations or fluctuations, probably caused to some extent by certain climatic conditions. These fluctuations are encountered in all the strains of this variety. A similar condition was found in the Eureka variety.

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

[The weights of annual production are expressed in pounds and

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
1. Lisbon strain:												
Green grade—												
1913–14	588– 7	2,191	26– 7	95	3– 6	13	0– 4	1	4–12	18	.....	.....
1914–15	712–13	2,610	30–11	132	6– 0	26	2– 3	9	39– 4	140	28– 6	103
1915–16	579– 8	2,129	30–10	116	13– 1	55	2–12	10	1–15	7	2–10	10
1916–17	489– 9	1,821	32– 6	131	5– 0	20	0– 4	1	5– 0	17	5–13	23
Average	592.58	2,187.75	30.03	118.50	6.86	28.50	1.36	5.25	12.73	45.50	12.27	45.33
Tree-Ripe grade—												
1913–14	47–14	205	10– 4	46	0–15	4	0– 8	3	2– 1	11	.....	.....
1914–15	170– 6	716	18– 3	91	2– 5	15	3–10	18	0– 3	1	0–10	3
1915–16	109– 8	494	8– 1	36	14–10	72	7– 8	39	4–11	27	1– 3	7
1916–17	103– 0	469	8–10	45	3– 4	18	0– 7	2	5–12	29	1– 5	7
Average	107.69	471.00	11.28	54.50	5.28	27.25	3.02	15.50	3.17	17.00	1.04	5.67
Cull grade—												
1913–14	10–12	97	0–10	4	0– 5	2	0– 4	2	2– 6	39	.....	.....
1914–15	33–15	221	4– 8	34	3–14	36	1–10	15	0– 4	2	0–11	4
1915–16	52– 7	311	5– 8	35	7– 5	41	4– 6	31	0– 2	1	0– 9	4
1916–17	47–11	324	3–10	20	0–12	5	0– 0	0	0– 0	0	0–13	7
Average	36.20	238.25	3.56	23.25	3.06	21.00	1.56	12.00	0.69	10.50	0.69	5.00
Total crop—												
1913–14	647– 1	2,493	37– 5	145	4–10	19	1– 0	6	9– 3	68	.....	.....
1914–15	917– 2	3,547	53– 6	257	12– 3	77	7– 7	42	39–11	143	29–11	110
1915–16	741– 7	2,934	44– 3	187	35– 0	168	14–10	80	6–12	35	4– 6	21
1916–17	640– 4	2,614	44–10	196	9– 0	43	0–11	3	10–12	46	7–15	37
Average	**736.47**	**2,897**	**44.88**	**196.25**	**15.20**	**76.75**	**5.94**	**32.75**	**16.59**	**73.00**	**14.00**	**56.00**
Variable fruits—												
1913–14	.....	800	.....	12	.....	0	.....	0	.....	2	.....	.....
1914–15	.....	597	.....	49	.....	8	.....	2	.....	22	.....	19
1915–16	.....	1,589	.....	43	.....	13	.....	4	.....	1	.....	3
1916–17	.....	1,273	.....	102	.....	17	.....	0	.....	14	.....	15
Average	.....	1,064.75	.....	51.50	.....	9.50	.....	1.50	.....	9.75	.....	12.33
Average seeds per fruit—												
1913–14	.....	4.13	.....	6	.....	6	.....	4	.....	3	.....	.....
1914–15	.....	4.39	.....	2	.....	8	.....	3	.....	3	.....	2
1915–16	.....	4.53	.....	5	.....	4	.....	4	.....	12	.....	8
Average	.....	4.36	.....	4.44	.....	6.00	.....	3.67	.....	5.89	.....	4.67
5. Bull strain:												
Green grade—												
1914–15	738–10	2,641	3– 7	13	.....	(1)	12– 9	48	114–10	411	57– 3	196
1915–16	587– 6	2,044	19–12	71	5– 0	19	5– 8	18	7– 1	25	27– 9	95
1916–17	540–13	1,934	6– 7	23	1– 2	4	8–10	30	52–13	183	94– 0	327
Average	622.27	2,206.33	9.88	35 67	3.06	11.50	8.90	32.00	58.17	206.33	59.58	206.00
Tree-Ripe grade—												
1914–15	85–13	335	0–13	4	.....	(1)	1– 6	8	0– 0	0	0– 4	1
1915–16	26– 9	115	2–12	11	0–13	4	4–15	24	1– 2	5	1– 7	7
1916–17	44– 9	169	0– 0	0	0–12	4	0– 6	2	0– 0	0	1–11	6
Average	52.31	206.33	1.19	5.00	0.78	4.00	2.23	11.33	0.38	1.67	1.13	4.67
Cull grade—												
1914–15	14– 8	85	0– 8	4	.....	(1)	0–12	5	0– 4	1	0– 5	2
1915–16	16– 9	83	1– 2	6	1–11	9	1– 2	8	0– 2	1	0– 4	2
1916–17	29– 2	177	0– 2	1	0– 3	1	0– 0	0	0–12	4	0–13	5
Average	20.06	115.00	0.58	3.67	0.94	5.00	0.63	4.33	0.38	2.00	0.46	3.00
Total crop—												
1914–15	838–15	3,061	4–12	21	.....	(1)	14–11	61	114–14	412	57–12	199
1915–16	630– 8	2,242	23–10	88	7– 8	32	11– 9	50	8– 5	31	29– 4	104
1916–17	614– 8	2,280	6– 9	24	2– 1	9	9– 0	32	53– 9	187	96– 8	338
Average	**694.65**	**2,527.67**	**11.65**	**44.33**	**4.78**	**20.50**	**11.75**	**47.67**	**58.92**	**210.00**	**61.17**	**213.67**

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[1] Fruit picked in August was carried away without being recorded.

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917, inclusive.
ounces, but the fractional averages are stated decimally in pounds.]

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
21-13	82	83-8	332	155-3	559	172-1	625	......	......	91-2	347	29-15	119
41-10	147	140-11	527	86-2	312	108-1	402	......	......	180-10	632	49-3	180
22-13	82	109-5	414	56-8	232	125-0	439	103-1	362	64-2	228	47-11	174
25-15	98	13-3	50	120-5	433	133-12	481	......	......	145-0	556	2-15	11
22.44	81.80	86.67	330.75	104.53	384.00	134.72	486.75	103.06	362.00	68.70	251.86	32.44	121.00
1-2	6	2-2	9	8-5	32	10-1	39	......	......	11-2	49	1-6	6
8-6	34	29-2	114	24-8	93	28-6	107	......	......	31-8	139	23-9	101
2-11	12	6-6	33	1-10	8	1-14	12	12-11	47	35-14	148	12-5	53
1-2	6	2-5	10	24-14	94	18-6	75	......	......	22-12	103	14-3	80
2.66	11.60	9.98	41.50	14.83	56.75	14.67	58.25	12.69	47.00	14.46	62.71	12.86	60.00
0-1	1	0-13	5	2-0	12	1-3	9	......	......	1-13	15	1-5	8
0-14	5	0-14	5	8-0	46	5-8	26	......	......	5-6	32	2-6	16
1-3	8	6-0	37	9-0	51	3-14	20	6-8	39	5-4	30	2-12	14
0-7	4	1-4	8	15-12	107	4-7	32	......	......	13-6	77	7-4	64
0.51	3.60	2.23	13.75	8.69	54.00	3.75	21.75	6.50	39.00	3.69	22.00	3.42	25.50
23-0	89	86-7	346	165-8	603	183-5	673	......	......	104-1	411	32-10	133
50-14	186	170-11	646	118-10	451	141-15	535	......	......	217-8	803	75-2	297
26-11	102	121-11	484	67-2	291	130-12	471	122-4	448	105-4	406	62-12	241
27-8	108	16-12	68	160-15	634	156-9	588	......	......	181-2	736	24-6	155
25.61	**97.00**	**98.89**	**386.00**	**128.05**	**494.75**	**153.14**	**566.75**	**122.25**	**448.00**	**86.85**	**336.57**	**48.72**	**206.50**
......	8	......	101	......	212	......	304	......	......	......	118	......	43
......	12	......	104	......	66	......	103	......	......	......	145	......	67
......	47	......	331	......	201	......	386	......	264	......	162	......	134
......	79	......	48	......	413	......	390	......	......	......	195	......	0
......	29.20	......	146.00	......	223.00	......	295.75	......	264.00	......	88.57	......	61.00
......	4	......	5	......	1	......	5	......	......	......	4	......	4
......	8	......	2	......	4	......	3	......	......	......	8	......	6
......	3	......	1	......	8	......	3	......	1	......	4	......	1
......	4.98	......	2.67	......	4.44	......	3.56	......	0.67	......	5.33	......	3.78
91-11	321	147-11	550	72-5	259	117-7	417	63-13	227	......	......	57-14	199
88-8	308	147-12	554	101-3	312	74-3	265	71-3	245	24-4	81	15-7	51
109-0	398	68-12	255	83-8	304	67-12	240	......	......	......	......	48-13	170
96.40	342.33	121.40	453.00	85.67	291.67	86.46	307.33	67.50	236.00	24.25	81.00	20.35	70.00
5-11	22	23-8	91	11-14	45	20-9	77	19-6	77	......	......	2-6	10
2-1	9	3-0	15	5-14	21	0-2	1	2-0	8	1-3	4	1-4	6
2-6	9	8-0	33	8-12	33	14-0	51	......	......	......	......	8-10	31
3.38	13.33	11.50	46.33	8.83	33.00	11.56	43.00	10.69	42.50	1.19	4.00	2.04	7.83
0-0	0	1-12	9	3-4	18	2-7	13	4-8	28	......	......	0-12	5
1-2	6	1-7	6	5-2	21	0-7	2	2-12	15	1-3	6	0-3	1
1-2	7	0-12	8	13-12	94	4-6	24	......	......	......	......	7-4	33
0.75	4.33	1.31	7.67	7.38	44.33	2.42	13.00	3.63	21.50	1.19	6.00	1.36	6.50
97-6	343	172-15	650	87-7	322	140-7	507	87-11	332	......	......	61-0	214
91-11	323	152-3	575	112-3	354	74-12	268	75-15	268	26-10	91	16-14	58
112-8	414	77-8	296	106-0	431	86-2	315	......	......	......	......	64-11	234
100.52	**360.00**	**134.21**	**507.00**	**101.88**	**369.00**	**100.44**	**363.33**	**81.81**	**300.00**	**26.63**	**91.00**	**23.76**	**84.33**

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
5. Bull strain—Continued.												
Variable fruits—												
1914–15	......	647	......	2	.....	(1)	.....	15	......	34	.....	20
1915–16	......	1,352	......	30	.....	6	.....	2	......	10	.....	51
1916–17	......	1,284	......	10	.....	0	.....	13	......	103	.....	183
Average	......	1,094.33	......	14.00	.....	3.00	.....	10.00	......	49.00	.....	84.67
Average seeds per fruit—												
1914–15	......	5.44	......	4	.....	(1)	.....	1	......	6	.....	4
1915–16	......	4.75	......	13	.....	2	.....	2	......	8	.....	5
Average	......	5.05	......	8.67	.....	2.33	.....	1.67	......	7.25	.....	4.83
6. Lisbon strain:												
Green grade—												
1913–14	535–14	1,967	4–11	17	2–0	8	1–2	4	5–4	21	.....	......
1914–15	740–4	2,653	9–7	39	5–4	22	3–11	13	60–9	229	65–12	234
1915–16	671–12	2,341	28–1	104	5–8	21	3–1	12	11–8	42	19–8	70
1916–17	444–8	1,630	25–7	104	2–7	9	3–3	12	7–6	26	17–2	63
Average	598.09	2,147.75	16.91	66.00	3.80	15.00	2.77	10.25	21.17	79.50	34.13	122.33
Tree-Ripe grade—												
1913–14	39—3	167	1–0	6	1–2	5	1–2	5	0–6	2	.....	......
1914–15	88–6	344	0–14	4	1–5	7	0–7	2	0–12	3	0–4	1
1915–16	52–0	234	10–10	45	3–4	16	3–0	15	5–14	32	1–12	10
1916–17	72–12	294	1–5	6	1–0	6	1–2	5	2–10	12	1–1	4
Average	63.08	259.75	3.45	15.25	1.67	8.50	1.42	6.75	2.41	12.25	1.02	5.00
Cull grade—												
1913–14	6–0	46	0–0	0	0–0	0	0–0	0	0–7	5	.....	......
1914–15	12–0	65	0–4	1	1–3	10	0–0	0	0–9	3	0–3	1
1915–16	37–4	226	3–7	22	4–0	27	9–1	63	1–1	9	0–2	1
1916–17	63–4	378	1–2	5	1–0	5	0–12	5	0–3	1	0–13	8
Average	29.63	178.75	1.20	7.00	1.55	10.50	2.45	17.00	0.56	4.50	0.38	3.33
Total crop—												
1913–14	581–1	2,180	5–11	23	3–2	13	2–4	9	6–1	28	.....	......
1914–15	840–10	3,062	10–9	44	7–12	39	4–2	15	61–14	235	66–3	236
1915–16	761–0	2,801	42–2	171	12–12	64	15–2	90	18–7	83	21–6	81
1916–17	580–8	2,302	27–14	115	4–7	20	5–1	22	10–3	39	19–0	75
Average	**690.80**	**2,586.25**	**21.56**	**88.25**	**7.02**	**34.00**	**6.64**	**34.00**	**24.14**	**96.25**	**35.52**	**130.67**
Variable fruits—												
1913–14	......	607	......	5	.....	1	.....	1	......	5	.....	......
1914–15	......	546	......	16	.....	9	.....	4	......	33	.....	27
1915–16	......	1,711	......	38	.....	4	.....	4	......	9	.....	37
1916–17	......	1,196	......	42	.....	5	.....	2	......	19	.....	42
Average	......	1,015.00	......	25.25	.....	4.75	.....	2.75	......	16.50	.....	35.33
Average seeds per fruit—												
1913–14	......	4.70	......	2	.....	4	.....	3	......	3	.....	......
1914–15	......	3.13	......	5	.....	3	.....	2	......	0	.....	0
1915–16	......	4.39	......	5	.....	6	.....	3	......	6	.....	7
Average	......	4.06	......	4.25	.....	4.88	.....	2.85	......	3.11	.....	3.33
10. Bull strain:												
Green grade—												
1914–15	706–2	2,507	0–11	3	.....	(1)	22–10	89	162–6	572	61–14	217
1915–16	572–10	2,105	11–14	44	0–4	1	2–14	10	9–0	32	24–9	88
1916–17	520–12	1,883	5–15	22	0–4	1	3–4	10	36–2	125	72–13	260
Average	599.83	2,165.00	6.17	23.00	0.25	1.00	9.58	36.33	69.17	243.00	53.08	188.33
Tree-Ripe grade—												
1914–15	65–12	250	0–3	1	.....	(1)	0–12	3	0–6	2	0–8	2
1915–16	26–3	116	0–14	4	0–3	1	1–12	9	1–7	6	1–13	8
1916–17	61–2	239	0–6	2	0–3	1	0–0	0	0–15	4	0–14	4
Average	51.02	201.67	0.48	2.33	0.19	1.00	0.83	4.00	0.92	4.00	1.06	4.67

[1] Fruit picked in August was carried away without being recorded.

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
......	95	......	216	......	70	......	120	......	40	......	......	......	35
......	182	......	428	......	229	......	202	......	141	......	45	......	2[illegible]
......	275	......	184	......	219	......	196	......	......	......	......	......	101
......	184.00	......	276.00	......	172.67	......	172.67	......	90.50	......	45.00	......	2[illegible]
......	5	......	4	......	3	......	8	......	8	......	......	......	11
......	5	......	2	......	4	......	4	......	2	......	6	......	4
......	5.40	......	3.17	......	3.33	......	5.67	......	5.00	......	6.00	......	7.50
64- 9	234	134- 3	521	106- 9	383	154- 8	542	......	......	44-15	168	18- 1	69
69- 8	248	144- 7	538	118- 5	413	85- 1	308	......	......	150- 7	507	27-13	102
77- 0	167	197-14	721	66- 2	256	110- 1	401	70-10	249	64-11	233	17-12	65
77-10	281	49-13	190	104- 3	380	85-14	307	......	......	64-12	233	6-11	25
57.74	186.00	131.58	492.50	98.80	358.00	108.88	389.50	70.63	249.00	46.40	163.00	17.58	65.25
4- 0	21	0- 6	2	11- 2	42	8- 5	33	......	......	10- 6	45	1- 6	6
5- 4	20	21- 0	81	21-14	83	16-10	63	......	......	13-14	54	6- 2	26
2- 4	9	4- 1	20	1- 9	8	0- 8	3	8-10	33	6-11	27	3-13	16
3- 6	14	5- 2	20	18-11	71	13- 7	50	......	......	20-11	81	4- 5	25
2.98	12.80	7.64	30.75	13.31	51.00	9.72	37.25	8.63	33.00	7.38	29.57	3.91	18.25
0-13	10	0-11	5	1- 0	6	1-12	9	......	......	1- 2	10	0- 3	1
0- 0	0	0- 9	3	3-12	17	0-15	5	......	......	3- 1	16	1- 8	9
1-12	9	4- 4	21	6- 1	34	2- 3	10	1-14	10	2- 1	11	1- 6	9
0- 4	2	2-11	18	16-14	107	3- 4	20	......	......	33- 5	181	3- 0	26
0.56	4.20	2.05	11.75	6.92	41.00	2.03	11.00	1.88	10.00	5.65	31.14	1.52	11.25
69- 6	265	135- 4	528	118-11	431	164- 9	584	......	......	56- 7	223	19-10	76
74-12	268	166- 0	622	143-15	513	102-10	376	......	......	167- 6	577	35- 7	137
81- 0	185	206- 3	762	73-12	298	112-12	414	81- 2	292	73- 7	271	22-15	90
81- 4	297	57-10	228	139-12	558	102- 9	377	......	......	118-12	495	14- 0	76
61.28	**203.00**	**141.27**	**535.00**	**119.03**	**450.00**	**120.63**	**437.75**	**81.13**	**292.00**	**59.43**	**223.71**	23.00	94.75
......	31	......	128	......	133	......	217	......	......	......	55	......	31
......	24	......	105	......	90	......	78	......	......	......	125	......	35
......	203	......	539	......	204	......	333	......	179	......	120	......	41
......	235	......	169	......	344	......	236	......	......	......	102	......	0
......	98.60	......	235.25	......	192.75	......	216.00	......	179.00	......	57.43	......	26.75
......	5	......	8	......	5	......	5	......	......	......	1	......	6
......	0	......	2	......	2	......	8	......	......	......	7	......	5
......	1	......	3	......	7	......	4	......	3	......	2	......	6
......	2.38	......	4.33	......	4.89	......	5.67	......	2.67	......	3.33	......	5.56
106-15	381	69- 0	258	99- 8	352	93-10	325	46-13	163	......	......	42-11	147
76- 4	267	159- 7	608	101- 3	402	66- 7	238	90- 0	307	21- 3	75	9- 9	33
88-14	340	46- 8	175	91- 9	335	89-10	320	......	......	......	......	85-13	295
90.69	329.33	91.65	347.00	97.42	363.00	83.23	294.33	68.41	235.00	21.18	75.00	23.01	79.17
9- 8	36	14- 2	56	8-12	32	14- 4	52	13-11	51	......	......	3-10	15
2- 1	9	0-14	4	5-14	31	0- 0	0	6- 5	22	3- 8	14	1- 8	8
5-10	23	6- 4	26	12-13	49	12- 1	45	......	......	......	......	22- 0	85
5.73	22.67	7.08	28.67	9.15	37.33	8.77	32.33	10.00	36.50	3.50	14.00	4.52	18.00

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
10. Bull strain—Continued.												
Cull grade—												
1914–15	10– 5	54	0– 5	2	.....	(1)	1– 5	6	0– 3	1	0– 0	0
1915–16	13– 7	69	1– 4	7	1– 1	6	0–10	4	0– 7	2	0– 0	0
1916–17	21– 7	131	1– 9	7	0– 0	0	0–15	7	0– 8	2	0– 5	2
Average	15.06	84.67	1.04	5.33	0.53	3.00	0.96	5.67	0.38	1.67	0.10	0.67
Total crop—												
1914–15	782– 3	2,811	1– 3	6	.....	(1)	24–11	98	162–15	575	62– 6	219
1915–16	612– 4	2,290	14– 0	55	1– 8	8	5– 4	23	10–14	40	26– 6	96
1916–17	603– 5	2,253	7–14	31	0– 7	2	4– 3	17	37– 9	131	74– 0	266
Average	**665.92**	**2,451.33**	**7.69**	**30.67**	**0.97**	**5.00**	**11.38**	**46.00**	**70.46**	**248.67**	**54.25**	**193.67**
Variable fruits—												
1914–15	......	551	......	1	.....	(1)	.....	23	......	62	.....	20
1915–16	......	1,329	......	18	.....	0	.....	0	......	8	.....	46
1916–17	......	1,262	......	11	.....	1	.....	2	......	74	.....	167
Average	......	1,047.33	......	10.00	.....	0.50	.....	8.33	......	48.00	.....	77.67
Average seeds per fruit												
1914–15	......	5.00	......	4	.....	(1)	.....	1	......	3	.....	4
1915–16	......	3.29	......	0	.....	4	.....	2	......	4	.....	3
Average	......	4.08	......	2.17	.....	4.00	.....	1.50	......	3.33	.....	3.25
13. Lisbon strain:												
Green grade—												
1913–14	576–15	2,206	26– 1	99	8–10	35	1– 6	6	6– 6	27	.....	......
1914–15	600– 2	2,180	17– 0	68	4– 0	18	1–10	7	9–14	39	14–12	55
1915–16	504– 1	1,867	52– 8	197	5– 3	22	2– 9	10	2– 5	9	2– 2	8
1916–17	397– 7	1,470	27– 2	107	0– 0	0	0–10	2	1– 1	4	2–10	10
Average	519.64	1,930.75	30.67	117.75	4.45	18.75	1.55	6.25	4.91	19.75	6.50	24.33
Tree-Ripe grade—												
1913–14	71–10	319	7–13	37	5–14	31	1–14	12	2–10	16	.....	......
1914–15	168–10	699	8– 6	42	0–15	6	1– 6	7	0– 7	3	0– 3	1
1915–16	93–15	432	23– 9	106	4– 9	23	9–12	49	5–14	32	1– 6	7
1916–17	79–13	347	6– 7	35	0– 8	3	0– 0	0	1– 1	5	0– 9	3
Average	103.50	449.25	11.55	55.00	2.97	15.75	3.25	17.00	2.50	14.00	0.71	3.67
Cull grade—												
1913–14	9– 0	67	1–12	15	0–14	6	0– 0	0	1– 4	10	.....	......
1914–15	24– 2	149	1– 6	12	2– 8	19	1–11	12	0– 3	1	0– 2	1
1915–16	52–11	312	7–10	43	9– 2	56	13–12	98	1– 2	9	0– 7	4
1916–17	49–14	352	1–13	9	0– 6	3	1– 5	8	0– 0	0	1– 0	10
Average	33.92	220.00	3.14	19.75	3.22	21.00	4.19	29.50	0.64	5.00	0.52	5.00
Total crop—												
1913–14	657– 9	2,592	35–10	151	15– 6	72	3– 4	18	10– 4	53	.....	......
1914–15	792–14	3,028	26–12	122	7– 7	43	4–11	26	10– 8	43	15– 1	57
1915–16	650–11	2,611	83–11	346	18–14	101	26– 1	157	9– 5	50	3–15	19
1916–17	527– 2	2,169	35– 6	151	0–14	6	1–15	10	2– 2	9	4– 3	23
Average	**657.06**	**2,600.00**	**45.36**	**192.5**	**10.64**	**55.50**	**8.98**	**52.75**	**8.05**	**38.75**	**7.73**	**33.00**
Variable fruits—												
1913–14	......	864	......	10	.....	2	.....	0	......	3	.....	......
1914–15	......	593	......	25	.....	6	.....	4	......	12	.....	6
1915–16	......	1,477	......	73	.....	4	.....	3	......	3	.....	3
1916–17	......	835	......	82	.....	2	.....	0	......	2	.....	8
Average	......	942.25	......	47.50	.....	3.50	.....	1.75	......	5.00	.....	5.67
Average seeds per fruit—												
1913–14	......	5.04	......	5	.....	10	.....	6	......	1	.....	......
1914–15	......	5.16	......	5	.....	2	.....	1	......	2	.....	2
1915–16	......	5.69	......	8	.....	11	.....	4	......	8	.....	5
Average	......	5.32	......	6.00	.....	7.56	.....	3.38	......	3.67	.....	3.67

[1] Fruit picked in August was carried away without being recorded.

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
0-11	4	1- 1	4	2-10	15	1- 2	5	2- 6	13	......	......	0-10	4
0-10	4	1-10	7	5- 2	24	0- 9	4	1- 0	5	0- 7	2	0-11	4
0- 0	0	0- 7	4	14-10	94	0- 0	0	......	......	......	......	3- 1	15
0.44	2.67	1.04	5.00	7.46	44.33	0.56	3.00	1.69	9.00	0.44	2.00	0.73	3.83
117- 2	421	84- 3	318	110-14	399	109- 0	382	62-14	227	......	......	46-15	166
78-15	280	161-15	619	112- 3	457	67- 0	242	97- 5	334	25- 2	91	11-12	45
94- 8	363	53- 3	205	119- 0	478	101-11	365	......	......	......	......	110-14	395
96.85	**354.67**	**99.77**	**380.67**	**114.02**	**444.67**	**92.56**	**329.67**	**80.09**	**280.50**	**25.13**	**91.00**	**28.26**	**101.00**
......	102	......	95	......	98	......	88	......	36	......	......	......	26
......	151	......	439	......	274	......	196	......	145	......	34	......	18
......	243	......	120	......	256	......	253	......	......	......	......	......	135
......	165.33	......	218.00	......	209.33	......	179.00	......	90.50	......	34.00	......	29.83
......	0	......	9	......	3	......	9	......	8	......	......	......	8
......	4	......	0	......	4	......	5	......	6	......	5	......	4
......	2.17	......	4.50	......	3.33	......	7.60	......	7.17	......	4.67	......	5.83
27- 0	103	96-14	382	183- 8	695	125-12	466	......	......	81-13	314	19- 9	79
34- 1	123	75-14	288	89-11	316	83-14	311	......	......	206-11	722	62-11	233
22- 0	82	97-14	368	81- 2	314	82- 6	299	99- 7	357	34- 6	124	22- 3	77
15-15	57	16-15	65	76- 9	275	120- 9	430	......	......	133-10	510	2- 6	10
19.80	73.00	71.89	275.75	107.72	400.00	103.14	376.50	99.44	357.00	65.21	238.57	26.70	99.75
2- 8	14	1- 6	6	21-15	84	9- 3	37	......	......	15-10	69	2-13	13
4- 2	16	16- 6	66	31- 8	117	36- 3	139	......	......	44- 1	186	25- 1	116
3- 4	15	3-10	20	4-12	31	0- 0	0	11- 0	42	12- 3	52	14- 0	55
0- 4	2	3- 4	13	12- 1	45	22- 9	88	......	......	26- 2	113	7- 0	40
2.03	9.40	6.16	26.25	17.56	69.25	16.98	66.00	11.00	42.00	14.00	60.00	12.22	56.00
0- 1	1	0- 0	0	2- 5	15	1- 5	8	......	......	1- 5	11	0- 2	1
0- 0	0	1- 5	8	3- 2	18	3-13	22	......	......	4- 4	23	5-12	33
0- 3	1	3- 6	16	9-10	43	1-10	9	2- 0	12	2- 7	12	1- 6	9
0-11	5	3- 2	22	14- 5	104	8- 9	62	......	......	12- 1	71	6-10	58
0.19	1.40	1.95	11.50	7.34	45.00	3.83	25.25	2.00	12.00	2.87	16.71	3.47	25.25
29- 9	118	98- 4	388	207-12	794	136- 4	511	......	......	98-12	394	22- 8	93
38- 3	139	93- 9	362	124- 5	451	123-14	472	......	......	255- 0	931	93- 8	382
25- 7	98	104-14	404	95- 8	388	84- 0	308	112- 7	411	49- 0	188	37- 9	141
16-14	64	23- 5	100	102-15	424	151-11	580	......	......	171-13	694	16- 0	108
22.01	**83.80**	**80.00**	**313.50**	**132.63**	**514.25**	**123.95**	**467.75**	**112.44**	**411.00**	**82.08**	**315.29**	**42.39**	**181.00**
......	14	......	96	......	317	......	264	......	......	......	128	......	30
......	20	......	57	......	107	......	112	......	......	......	181	......	63
......	58	......	329	......	283	......	267	......	285	......	91	......	78
......	47	......	58	......	258	......	185	......	......	......	193	......	0
......	27.80	......	135.00	......	241.25	......	207.00	......	285.00	......	84.71	......	42.75
......	5	......	3	......	3	......	5	......	......	......	6	......	6
......	4	......	5	......	7	......	7	......	......	......	15	......	7
......	4	......	5	......	1	......	9	......	3	......	8	......	3
......	4.13	......	4.88	......	3.78	......	6.75	......	2.67	......	9.44	......	5.33

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
17. Lisbon strain:												
Green grade—												
1913–14	463– 4	1,738	22– 6	82	4–10	17	0– 4	1	2– 6	10	......	......
1914–15	719–14	2,588	9–12	38	4– 4	16	19–11	74	90–12	330	81– 3	288
1915–16	502– 8	1,825	32– 7	114	6– 7	26	6– 0	21	12–12	46	23–10	85
1916–17	571–11	2,064	19– 4	73	1– 3	5	1– 2	4	10– 8	36	19–14	71
Average	564.33	2,053.75	20.95	76.75	4.13	16.00	6.77	25.00	29.09	105.50	41.56	148.00
Tree-Ripe grade—												
1913–14	15–14	75	4– 2	21	0–11	4	0– 6	2	1– 1	6	......	......
1914–15	60–14	242	3– 0	13	0– 3	1	2– 3	12	0– 0	0	0– 8	2
1915–16	49–11	233	14– 0	62	3–14	20	6–11	33	4– 5	23	0–10	3
1916–17	73– 2	318	2– 6	12	0– 3	1	0– 6	2	4– 9	20	0–12	3
Average	49.89	217.00	5.88	27.00	1.23	6.50	2.41	12.25	2.48	12.25	0.63	2.67
Cull grade—												
1913–14	7– 8	55	0–11	7	0– 4	2	0– 0	0	1– 6	10	......	......
1914–15	10– 4	57	0– 8	2	0–14	6	0– 7	3	0– 0	0	0– 3	1
1915–16	22– 6	129	2– 0	13	3– 6	21	4– 9	30	0– 8	3	0–12	5
1916–17	80–10	528	0– 5	2	0– 4	1	1– 2	8	0– 0	0	0– 8	4
Average	30.19	192.25	0.88	6.00	1.19	7.50	1.53	10.25	0.47	3.25	0.48	3.33
Total crop—												
1913–14	486–10	1,868	27– 3	110	5– 9	23	0–10	3	4–13	26	......	......
1914–15	791– 0	2,887	13– 4	53	5– 5	23	22– 5	89	90–12	330	81–14	291
1915–16	574– 9	2,187	48– 7	189	13–11	67	17– 4	84	17– 9	72	25– 0	93
1916–17	725– 7	2,910	21–15	87	1–10	7	2–10	14	15– 1	56	21– 2	78
Average	**644.41**	**2,463.00**	**27.70**	**109.75**	**6.55**	**30.00**	**10.70**	**47.50**	**32.05**	**121.00**	**42.67**	**154.00**
Variable fruits—												
1913–14	......	757	......	7	......	2	......	0	......	0	......	......
1914–15	......	569	......	19	......	2	......	31	......	41	......	49
1915–16	......	1,283	......	40	......	4	......	7	......	14	......	36
1916–17	......	1,260	......	44	......	1	......	3	......	16	......	40
Average	......	967.25	......	27.50	......	2.25	......	10.25	......	17.75	......	41.67
Average seeds per fruit—												
1913–14	......	2.36	......	2	......	4	......	5	......	2	......	......
1914–15	......	2.29	......	3	......	1	......	3	......	3	......	2
1915–16	......	2.11	......	6	......	2	......	1	......	4	......	2
Average	......	2.14	......	3.56	......	2.33	......	2.63	......	3.14	......	1.67
22. Sporting strain:												
Green grade—												
1913–14	496–14	1,894	(1)	......	(2)	......	1– 5	5	2– 5	9	......	......
1914–15	672– 0	2,434	17– 3	70	2–10	11	2– 5	9	51– 2	189	42– 5	151
1915–16	534– 5	1,970	16– 9	73	11–14	50	2– 5	9	5– 0	19	6–12	24
1916–17	374–10	1,401	13–11	57	2– 6	10	2– 1	7	6– 8	24	4–10	55
Average	519.45	1,924.75	15.81	66.67	5.63	23.67	2.00	7.50	16.23	60.25	17.90	76.67
Tree-Ripe grade—												
1913–14	12– 7	54	(1)	......	(2)	......	0– 3	1	1– 0	5	......	......
1914–15	123– 2	426	7– 0	36	1– 1	6	2– 2	11	1– 3	5	0– 3	1
1915–16	56– 9	263	15– 7	68	6–15	36	4– 7	24	3– 6	18	0– 3	1
1916–17	87– 6	313	0– 7	2	1– 6	8	0–10	3	2– 7	10	0–11	4
Average	69.88	264.00	7.63	35.33	3.13	16.67	1.84	9.75	2.00	9.50	0.35	2.00
Cull grade—												
1913–14	6– 5	50	(1)	......	(2)	......	1– 1	10	0– 0	0	......	......
1914–15	17– 9	107	1– 8	12	0–11	5	0–12	5	0– 6	2	0– 8	3
1915–16	43– 2	263	8–11	54	12– 7	78	5– 7	41	0–11	6	0– 0	0
1916–17	53–10	323	1– 0	6	0–13	5	0–10	4	0– 0	0	0– 4	2
Average	30.16	185.75	3.73	24.00	4.65	29.33	1.97	15.00	0.27	2.00	0.25	1.67

[1] This tree was not included in the performance-record plat until September, 1913.
[2] Fruit picked in August was carried away without being recorded.

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
43- 0	158	125- 9	488	160- 4	586	62- 4	237	......	......	29- 9	110	13- 0	49
68-10	245	135-15	501	89- 3	314	66-15	243	......	......	105- 4	364	48- 5	175
63- 0	218	121- 2	451	84- 4	323	53- 9	193	52- 8	182	28-14	103	17-15	63
46-14	174	39- 2	145	121- 0	446	153-13	515	......	......	157- 9	590	1- 6	5
44.30	159.00	105.44	396.25	113.67	417.25	84.14	297.00	52.50	182.00	45.89	166.71	20.16	73.00
0-10	4	0- 0	0	1- 6	5	3- 0	14	......	......	3- 8	14	1- 2	5
7- 0	26	16-10	65	11- 0	41	9- 3	35	......	......	7- 7	31	3-12	16
6-12	29	4- 8	24	1- 1	6	0- 0	0	2-14	12	2- 1	9	2-15	12
0-14	4	1-14	9	4- 9	18	11- 5	43	......	......	40- 6	177	5-14	29
3.05	12.60	5.75	24.50	4.50	17.50	5.88	23.00	2.88	12.00	7.63	33.00	3.42	15.50
0- 4	3	0-10	4	1-14	15	1- 4	7	......	......	0-13	5	0- 6	2
0-14	5	1- 4	6	2- 6	10	0- 6	3	......	......	2- 0	13	1- 6	8
0-14	5	1- 8	7	3-12	20	1- 0	4	2- 5	12	1- 6	7	0- 6	2
0- 4	2	0- 4	2	15- 2	104	6-15	44	......	......	33-10	203	22- 4	158
0.45	3.00	0.91	4.75	5.78	37.25	2.39	14.50	2.31	12.00	5.40	32.57	6.09	42.05
43-14	165	126- 3	492	163- 8	606	66- 8	258	......	......	33-14	129	14- 8	56
76- 8	276	153-13	572	102- 9	365	76- 8	281	......	......	114-11	408	53- 7	199
70-10	252	127- 2	482	89- 1	349	54- 9	197	57-11	206	32- 5	119	21- 4	77
48- 0	180	41- 4	156	140-11	568	172- 1	602	......	......	231- 9	970	29- 8	192
47.80	**174.60**	**112.09**	**425.50**	**123.95**	**472.00**	**92.41**	**334.50**	**57.69**	**206.00**	**58.92**	**232.29**	**29.67**	**131.00**
......	40	......	257	......	287	......	83	......	......	......	63	......	18
......	52	......	69	......	63	......	90	......	......	......	104	......	49
......	148	......	356	......	256	......	163	......	160	......	50	......	49
......	128	......	103	......	252	......	414	......	......	......	254	......	5
......	73.60	......	196.25	......	214.50	......	187.50	......	160.00	......	67.29	......	30.25
......	3	......	4	......	1	......	2	......	......	......	2	......	1
......	2	......	0	......	1	......	1	......	......	......	4	......	6
......	0	......	4	......	0	......	5	......	1	......	0	......	1
......	1.67	......	2.50	......	0.89	......	2.38	......	0.33	......	2.00	......	2.67
72- 1	303	138-10	518	166- 9	610	57- 4	222	......	......	42- 0	163	16-12	64
73-10	260	118-10	439	83- 8	300	100- 4	364	......	......	135- 1	472	45- 6	169
61- 0	210	137-11	517	78-12	308	67- 3	241	86- 1	302	34-12	122	26- 6	95
53- 1	196	19-14	75	87- 4	315	104- 4	366	......	......	73-13	270	7- 2	26
51.95	193.80	103.70	387.25	104.02	383.25	82.23	298.25	86.06	302.00	40.80	146.71	23.91	88.50
0-10	2	0- 4	1	1-14	8	2-14	13	......	......	4-10	20	1- 0	4
6- 2	22	15-13	64	10-12	41	25- 8	98	......	......	19- 1	78	34- 5	64
3-11	16	1- 2	6	5- 6	28	0- 0	0	0-12	3	11-12	47	3- 8	16
1- 2	5	1- 2	5	9- 6	34	30- 3	67	......	......	31- 0	125	9- 0	50
2.31	9.00	4.58	19.00	6.84	27.75	14.64	44.50	0.75	3.00	9.49	38.57	11.95	33.50
0-10	4	0-10	5	2- 8	19	0- 7	4	......	......	0-10	5	0- 7	3
0- 2	1	1- 6	8	1- 6	7	2- 6	14	......	......	4-10	29	3-14	21
1- 2	8	2- 8	11	6-12	39	1- 6	6	1-14	9	1-14	9	0- 6	2
0- 7	3	1- 2	7	13- 8	85	1-14	13	......	......	30- 0	166	4- 0	32
0.46	3.20	1.41	7.75	6.03	37.50	1.52	9.25	1.88	9.00	5.30	29.86	2.17	14.50

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
22. Sporting strain—Contd.												
Total crop—												
1913-14	515–10	1,998	(1)	......	(1)	......	2– 9	16	3– 5	14	......	......
1914-15	812–11	2,967	25–11	118	4– 6	22	5– 3	25	52–11	196	43– 0	155
1915-16	634– 0	2,496	40–11	195	31– 4	164	12– 3	74	9– 1	43	6–15	25
1916-17	515–10	2,037	15– 2	65	4– 9	23	3– 5	14	8–15	34	5– 9	61
Average	**619. 48**	**2,374. 50**	**27. 16**	**126. 00**	**13. 40**	**69. 67**	**5. 81**	**32. 25**	**18. 50**	**71. 75**	**18. 50**	**80. 33**
Variable fruits—												
1913-14	......	1,064	......	(1)	......	(1)	......	3	......	6	......	......
1914-15	......	1,061	......	46	......	6	......	9	......	74	......	32
1915-16	......	1,455	......	61	......	26	......	11	......	12	......	17
1916-17	......	1,225	......	37	......	5	......	4	......	25	......	41
Average	......	1,201. 25	......	46. 00	......	12. 33	......	6. 75	......	29. 25	......	30. 00
Average seeds per fruit..												
1913-14	......	3. 13	......	(1)	......	(1)	......	5	......	0	......	......
1914-15	......	2. 93	......	3	......	1	......	1	......	1	......	3
1915-16	......	3. 94	......	3	......	3	......	1	......	6	......	5
Average	......	3. 38	......	3. 17	......	2. 17	......	2. 22	......	2. 75	......	3. 80
24. Bull strain:												
Green grade—												
1914-15	590– 3	2,146	1–10	6	......	(2)	11– 4	42	95–14	353	......	(2)
1915-16	540– 8	1,896	16– 2	58	6– 2	26	3–11	14	4– 9	17	16– 1	56
1916-17	505– 0	1,803	6– 0	22	1– 6	6	4–13	17	35– 8	122	76– 0	267
Average	545. 23	1,948. 33	7. 92	28. 67	3. 75	16. 0	6. 58	24. 33	45. 31	164. 00	46. 03	161. 50
Tree-Ripe grade—												
1914-15	99– 0	381	0–10	3	......	(2)	0– 3	1	0– 0	0	......	(2)
1915-16	17– 9	78	0–12	3	1–15	9	2– 0	10	0–15	5	1– 8	7
1916-17	37– 1	145	0–14	4	0– 5	2	0– 8	2	0– 3	1	1– 1	4
Average	51. 21	201. 33	0. 75	3. 33	1. 13	5. 50	0. 90	4. 33	0. 38	2. 00	1. 28	5. 50
Cull grade—												
1914-15	11– 0	58	0– 4	2	......	(2)	0–13	5	0– 3	1	......	(2)
1915-16	12– 8	71	1– 4	8	1–14	11	0–10	6	0– 6	2	0– 7	3
1916-17	30–12	216	0–11	3	0– 2	1	1– 6	10	1– 6	10	0– 3	2
Average	18. 08	115. 00	0. 73	4. 33	1. 00	6. 00	0. 94	7. 00	0. 65	4. 33	0. 31	2. 50
Total crop—												
1914-15	700– 3	2,585	2– 8	11	......	(2)	12– 4	48	96– 1	354	......	(2)
1915-16	570– 9	2,045	18– 2	69	9–15	46	6– 5	30	5–14	24	18– 0	66
1916-17	572–13	2,164	7– 9	29	1–13	9	6–11	29	37– 1	133	77– 4	273
Average	**614. 52**	**2,264. 67**	**9. 40**	**36. 33**	**5. 88**	**27. 50**	**8. 42**	**35. 67**	**46. 33**	**170. 33**	**47. 63**	**169. 50**
Variable fruits—												
1914-15	......	582	......	4	......	(2)	......	10	......	28	......	(2)
1915-16	......	1,373	......	15	......	3	......	3	......	8	......	35
1916-17	......	1,096	......	12	......	1	......	9	......	56	......	140
Average	......	1,017. 00	......	10. 33	......	2. 00	......	7. 33	......	30. 67	......	87. 50
Average seeds per fruit—												
1914-15	......	6. 12	......	2	......	(2)	......	3	......	0	......	(2)
1915-16	......	4. 50	......	2	......	4	......	6	......	12	......	2
Average	......	5. 20	......	2. 00	......	4. 00	......	4. 50	......	7. 20	......	2. 00
26. Lisbon strain:												
Green grade—												
1913-14	418–11	1,544	15– 6	52	5– 3	20	1–10	5	12– 5	51	45– 5	......
1914-15	725– 9	2,587	8– 2	33	7– 4	28	8–10	35	40–11	149	1– 2	163
1915-16	510–14	1,844	35– 1	129	16– 7	65	1– 5	5	5– 9	20	5–14	61
1916-17	458– 2	1,717	13–13	55	3–10	15	2–15	11	6–10	23	5–14	23
Average	528. 31	1,923. 00	18. 09	67. 25	8. 13	32. 00	3. 63	14. 00	16. 30	60. 75	22. 77	82. 33

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[1] This tree was not included in the performance-record plat until September, 1913.
[2] Fruit picked in August and November were carried away without being recorded.

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
73- 5	309	139- 8	524	170-15	637	60- 9	239	......	......	47- 4	188	18- 3	71
79-14	283	135-13	511	95-10	348	128- 2	476	......	......	158-12	579	83- 9	254
65-13	234	141- 5	534	90-14	375	68- 9	247	88-11	314	48- 6	178	30- 4	113
54-10	204	22- 2	87	110- 2	434	136- 5	446	......	......	134-13	561	20- 2	108
54.73	**206.00**	**109.69**	**414.00**	**116.89**	**448.50**	**98.39**	**352.00**	**88.69**	**314.00**	**55.60**	**215.14**	**38.03**	**136.50**
......	141	......	280	......	337	......	143	......	......	......	111	......	43
......	52	......	181	......	164	......	193	......	......	......	194	......	110
......	171	......	416	......	282	......	221	......	80	......	94	......	64
......	173	......	66	......	269	......	374	......	......	......	211	......	20
......	107.40	......	235.75	......	263.00	......	232.75	......	80.00	......	87.14	......	59.25
......	5	......	3	......	5	......	4	......	......	......	2	......	1
......	3	......	4	......	0	......	5	......	......	......	......	......	7
......	2	......	6	......	6	......	0	......	5	......	6	......	3
......	3.22	......	4.44	......	3.67	......	3.38	......	5.33	......	4.17	......	3.44
90- 7	319	134-14	502	40-13	152	83-13	311	76- 8	270	......	......	55- 0	191
70-14	251	105-10	407	56- 4	220	109- 3	325	105- 3	358	24- 1	87	22-12	77
115- 4	426	36- 4	135	91- 8	320	75-5	268	......	......	......	......	63- 0	220
92.19	332.00	92.25	348.00	62.85	230.67	89.44	301.33	90.84	314.00	24.06	87.00	23.46	81.33
11- 9	42	37-14	145	12- 3	46	14- 5	55	19- 8	78	......	......	2-12	11
1- 5	5	0-13	3	1-13	10	0- 0	0	1-12	6	2- 6	10	2- 6	10
1- 5	5	3- 6	14	4- 0	14	6- 9	24	......	......	......	......	18-14	75
4.73	17.33	14.02	54.00	6.00	23.33	6.96	26.33	10.63	42.00	2.38	10.00	4.00	16.00
0-10	3	2- 4	10	1-12	9	2- 0	9	2-11	16	......	......	0- 7	3
0- 0	0	0-10	3	1- 8	8	0-14	5	3- 4	16	0-14	5	0-13	4
0- 0	0	1- 0	7	19-12	146	1-14	14	......	......	......	......	4- 6	23
0.21	1.00	1.29	6.67	7.67	54.33	1.58	9.33	2.97	16.00	0.88	5.00	0.94	5.00
102-10	364	175- 0	657	54-12	207	100- 2	375	98-11	364	......	......	58- 3	205
72- 3	256	107- 1	413	59- 9	238	110- 1	330	110- 3	380	27- 5	102	25-15	91
116- 9	431	40-10	156	115- 4	480	83-12	306	......	......	......	......	86- 4	318
97.13	**350.33**	**107.56**	**408.67**	**76.52**	**308.33**	**97.98**	**337.00**	**104.44**	**372.00**	**27.31**	**102.00**	**28.40**	**102.33**
......	89	......	172	......	71	......	83	......	80	......	......	......	45
......	169	......	294	......	168	......	308	......	298	......	43	......	29
......	272	......	86	......	195	......	205	......	......	......	......	......	120
......	176.67	......	184.00	......	144.67	......	198.67	......	189.00	......	43.00	......	32.33
......	8	......	7	......	12	......	7	......	6	......	......	......	8
......	2	......	3	......	5	......	1	......	2	......	12	......	3
......	5.60	......	4.33	......	8.33	......	4.60	......	3.83	......	11.67	......	5.33
35- 7	130	118-3	448	128- 5	473	54- 3	193	......	......	39- 1	138	9- 0	34
67-13	242	121-1	454	142-12	494	92- 0	342	......	......	153- 5	511	38-10	136
67- 8	243	88-4	352	90- 1	340	55- 9	198	86-13	264	30- 6	106	16-13	61
10- 8	40	18-5	70	73- 4	271	121-11	444	......	......	201- 6	764	0- 2	1
36.25	131.00	86.45	331.00	108.59	394.50	80.86	294.25	86.81	264.00	60.59	217.00	16.14	58.00

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
26. Lisbon strain—Contd.												
Tree-Ripe grade—												
1913–14	21– 9	93	2– 2	11	1– 1	5	0–10	3	0–10	3	......	......
1914–15	87–12	346	2– 1	11	0– 0	0	0– 4	1	0–03	1	0– 0	0
1915–16	53–14	244	12–10	51	3–15	19	4– 1	23	4– 9	24	5– 3	25
1916–17	58–11	259	4– 6	22	1– 2	7	0–12	4	0– 8	2	2– 6	12
Average	55.47	235.50	5.30	23.75	1.53	7.75	1.42	7.75	1.47	7.50	2.52	12.33
Cull grade—												
1913–14	4– 0	26	1– 2	10	0– 3	1	0– 2	1	0–10	3	......	......
1914–15	14– 0	74	0–12	5	0– 0	0	0– 8	3	0– 4	2	0– 2	1
1915–16	22– 1	123	3– 6	16	2– 5	12	3– 6	23	0– 0	0	0–10	4
1916–17	44– 3	313	0–12	3	0–11	3	0–10	5	0– 0	0	0– 5	4
Average	21.06	134.00	1.50	8.50	0.80	4.00	1.16	8.00	0.22	1.25	0.35	3.00
Total crop—												
1913–14	444– 4	1,663	18–10	73	6– 7	26	2– 6	9	13– 9	57	......	......
1914–15	827– 5	3,007	10–15	49	7– 4	28	9– 6	39	41– 2	152	45– 7	164
1915–16	586–13	2,211	51– 1	196	22–11	96	8–12	51	10– 2	44	22–15	90
1916–17	561– 0	2,289	18–15	80	5– 7	25	4– 5	20	7– 2	25	8– 9	39
Average	**604.84**	**2,292.50**	**24.89**	**99.50**	**10.45**	**43.75**	**6.20**	**29.75**	**17.98**	**69.50**	**25.65**	**97.67**
Variable fruits—												
1913–14	......	453	......	9	.....	1	.....	0	......	14	.....	......
1914–15	......	409	......	12	.....	3	.....	3	......	19	.....	20
1915–16	......	1,273	......	37	.....	11	.....	0	......	4	.....	15
1916–17	......	877	......	32	.....	9	.....	1	......	8	.....	9
Average	.....	753.00	......	22.50	.....	6.00	.....	1.00	......	11.25	.....	14.67
Average seeds per fruit—												
1913–14	......	2.07	......	2	.....	3	.....	1	......	2	.....	......
1914–15	......	1.43	......	.2	.....	0	.....	2	......	0	.....	0
1915–16	......	2.79	......	5	.....	6	.....	3	......	4	.....	2
Average	......	2.13	......	3.00	.....	3.71	.....	2.00	......	1.75	.....	1.20
29. Open strain:												
Green grade—												
1913–14	483– 1	1,780	20–15	71	17– 6	70	3–15	17	6– 7	27	......	......
1914–15	541– 5	1,971	13– 1	55	1–13	8	4– 3	16	24– 5	95	18– 0	65
1915–16	368– 4	1,310	82–12	306	19–11	78	1–10	7	4–15	19	9–12	35
1916–17	307– 5	1,157	17–15	64	5– 5	20	5– 0	18	5– 5	20	3–12	15
Average	424.98	1,554.50	33.67	124.00	11.05	44.00	3.69	14.50	10.25	40.25	10.50	38.33
Tree-Ripe grade—												
1913–14	52– 9	220	2–12	13	0–14	4	2– 0	12	5–10	28	......	......
1914–15	177–12	736	2–12	14	1– 0	6	3–12	20	0–11	3	0–15	5
1915–16	75– 0	334	17– 2	69	8– 7	37	8– 9	41	9– 1	46	7– 6	39
1916–17	122–11	552	3– 0	18	1– 5	6	0– 0	0	9– 2	40	3– 8	18
Average	107.00	460.50	6.41	28.50	2,91	13.25	3.58	18.25	6.13	29.25	3.95	20.67
Cull grade—												
1913–14	15– 2	110	1–10	15	1– 0	6	1– 2	12	4–15	35	.....	......
1914–15	36– 7	210	1– 0	6	3–12	24	0– 8	3	0– 5	2	0– 8	3
1915–16	60– 2	321	27– 6	132	7–14	43	9–12	63	1– 5	7	1– 0	8
1916–17	121– 3	780	1–11	8	0– 7	3	0–14	5	0–11	5	1–14	16
Average	58.22	355.25	7.92	40.25	3.27	19.00	3.06	20.75	1.81	12.25	1.12	9.00
Total crop—												
1913–14	550–12	2,110	25– 5	99	19– 4	80	7– 1	41	17– 0	90	.....	......
1914–15	755– 8	2,917	16–13	75	6– 9	38	8– 7	39	25– 5	100	19– 7	73
1915–16	503– 6	1,965	127– 4	507	36– 0	158	19–15	111	15– 5	72	18– 2	82
1916–17	551– 3	2,489	22–10	90	7– 1	29	5–14	23	15– 2	65	9– 2	49
Average	**590.20**	**2,370.25**	**48.00**	**192.75**	**17.22**	**76.25**	**10.33**	**53.50**	**18.19**	**81.75**	**15.56**	**68.00**
Variable fruits—												
1913–14	......	273	......	9	.....	1	.....	0	......	1	.....	......
1914–15	......	230	......	14	.....	0	.....	1	......	4	.....	5
1915–16	......	812	......	33	.....	12	.....	5	......	6	.....	12
1916–17	......	575	......	40	.....	3	.....	3	......	4	.....	0
Average	......	472.50	......	24.00	.....	4.00	.....	2.25	......	3.75	.....	5.67

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
2- 3	11	0- 8	3	4- 5	16	5- 0	19	......	......	3- 9	15	1- 9	7
3-15	15	17- 4	69	18- 0	69	20- 2	77	......	......	20- 5	80	5-10	23
5-11	26	0- 8	2	1- 0	6	0- 0	0	3- 9	14	8- 4	34	4- 8	20
0-12	4	2- 7	10	4- 9	18	7-10	31	......	......	34- 3	149	0- 0	0
2.51	11.20	5.17	21.00	6.97	27.25	8.19	31.75	3.56	14.00	9.47	39.71	2.92	12.50
0- 6	3	0- 0	0	0-15	4	0- 6	2	......	......	0- 2	1	0- 2	1
0- 1	1	1- 5	6	4- 7	22	2- 6	12	......	......	2- 6	13	1-13	9
0- 9	6	0-11	4	5-14	33	0- 9	3	1-11	8	2- 9	12	0- 7	2
0- 4	2	1-13	15	14- 0	105	3- 0	23	......	......	10- 2	54	12-10	99
0.25	2.40	0.95	6.25	6.31	41.00	1.58	10.00	1.69	8.00	2.17	11.43	3.75	27.75
38- 0	144	118-11	451	133- 9	493	59- 9	214	......	......	42-12	154	10-11	42
71-13	258	139-10	529	165- 3	585	114- 8	431	......	......	176- 0	604	46- 1	168
73-12	275	89- 7	358	96-15	379	56- 2	201	92- 1	286	41- 3	152	21-12	83
11- 8	46	22- 9	95	91-13	394	132- 5	498	......	......	245-11	967	12-12	100
39.01	**144.60**	**92.58**	**358.25**	**121.88**	**462.75**	**90.63**	**336.00**	**92.06**	**286.00**	**72.23**	**268.14**	**22.81**	**98.25**
......	17	......	115	......	149	......	80	......	......	......	49	......	19
......	26	......	46	......	72	......	45	......	......	......	125	......	38
......	179	......	273	......	294	......	152	......	213	......	58	......	37
......	31	......	56	......	164	......	313	......	......	......	253	......	1
......	50.60	......	122.50	......	169.75	......	147.50	......	213.00	......	69.29	......	23.75
......	2	......	3	......	2	......	2	......	......	......	1	......	3
......	0	......	1	......	2	......	1	......	......	......	4	......	2
......	0	......	2	......	1	......	0	......	0	......	2	......	7
......	0.78	......	1.88	......	1.78	......	1.38	......	0	......	2.67	......	3.78
31- 2	116	103- 8	395	173- 1	624	54- 1	191	......	......	52- 4	189	20- 6	80
27-12	101	57-13	219	73- 1	261	109-14	403	......	......	78- 2	283	133- 5	465
21-12	70	48- 1	174	52-13	191	53- 0	182	43- 2	141	21- 7	74	9- 5	33
26- 2	105	13- 7	53	43-13	166	81-15	300	......	......	104- 7	395	0- 4	1
21.35	78.40	55.70	210.25	85.69	310.50	74.72	269.00	43.13	141.00	36.61	134.43	40.81	144.75
2- 8	11	0-12	3	20- 9	77	4- 9	19	......	......	9- 8	39	3- 7	14
10- 5	40	23-13	97	24- 5	93	30-14	122	......	......	30-12	135	48- 9	201
2- 6	12	2- 2	11	1- 8	8	0- 0	0	3- 6	12	11- 7	44	3-10	15
5- 7	20	8- 4	40	19-14	77	18- 4	82	......	......	53-15	251	0- 0	0
4.12	16.60	8.73	37.75	16.56	63 75	13.42	55.75	3.38	12.00	15.09	67.00	13.91	57.50
0- 3	2	1- 6	7	0-10	5	1-15	12	......	......	1-12	12	0- 9	4
0- 9	4	2- 0	8	3-15	20	5- 4	32	......	......	9-12	55	8-14	53
0- 5	2	0-12	5	3-12	19	1- 3	7	4- 0	22	1- 7	7	1- 6	6
0-10	5	2-10	22	21- 1	136	8-10	65	......	......	51-10	287	31- 1	228
0.34	2.60	1.69	10.50	7.34	45.00	4.25	29.00	4.00	22.00	9.22	51.57	10.47	72.75
33-13	129	105-10	405	194- 4	706	60- 9	222	......	......	63- 8	240	24- 6	98
38-10	145	83-10	324	101- 5	374	146- 0	557	......	......	118-10	473	190-12	719
24- 7	84	50-15	190	58- 1	218	54- 3	189	50- 8	175	34- 5	125	14- 5	54
32- 3	130	24- 5	115	84-12	379	108-13	447	......	......	210- 0	933	31- 5	229
25.81	**97.60**	**66.13**	**258.50**	**109.59**	**419.25**	**92.39**	**353.75**	**50.50**	**175.00**	**60.91**	**253.00**	**65.19**	**275.00**
......	24	......	48	......	113	......	42	......	......	......	32	......	3
......	7	......	11	......	14	......	53	......	......	......	44	......	77
......	45	......	146	......	162	......	162	......	103	......	88	......	38
......	45	......	35	......	106	......	196	......	......	......	140	......	3
......	24.20	......	60.00	......	98.75	......	113.25	......	103.00	......	43.43	......	30.25

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
29. Open strain—Contd.												
Average seeds per fruit—												
1913–14	......	3.13	......	3	.....	3	.....	3	......	1	.....	......
1914–15	......	4.76	......	6	.....	3	.....	4	......	1	.....	1
1915–16	......	5.86	......	10	.....	5	.....	7	......	5	.....	3
Average	......	4.65	......	6.11	.....	3.44	.....	4.89	......	2.11	.....	2.00
39. Open strain:												
Green grade—												
1913–14	507– 0	1,903	23– 1	82	10–15	41	1– 9	6	6– 5	26	.....	......
1914–15	462–15	1,680	21– 0	85	6– 1	26	5–12	25	3– 7	14	8– 6	30
1915–16	245–12	880	57–14	212	14–10	58	4– 6	17	2– 7	9	1–11	6
1916–17	358–12	1,330	8–12	36	8– 2	30	4– 4	16	5– 3	19	10– 8	41
Average	393.61	1,448.25	27.67	103.75	9.94	38.75	3.98	16.00	4.34	17.00	6.85	25.67
Tree-Ripe grade—												
1913–14	63–12	286	1– 3	5	2– 8	12	1– 3	7	7–10	45	.....	......
1914–15	209–11	881	5– 9	25	1– 8	9	3–13	21	0– 9	3	4–12	26
1915–16	75–10	352	24–11	101	4–12	22	18–7	89	8– 5	52	4– 0	21
1916–17	87–13	381	3– 1	18	1– 6	7	0– 0	0	10– 2	43	4– 4	22
Average	109.22	475.00	8.63	37.25	2.53	12.50	5.86	29.25	6.66	35.75	4.33	23.00
Cull grade—												
1913–14	16–14	120	0–14	8	0– 2	1	0– 3	1	7– 3	53	.....	......
1914–15	41– 6	241	1–10	9	4– 6	26	2– 8	16	0– 0	0	0–13	6
1915–16	54– 8	327	20– 3	105	8– 8	69	13– 2	80	1– 6	9	1– 2	9
1916–17	95– 7	596	1– 6	8	0– 8	3	0–10	4	0– 0	0	0–12	6
Average	52.05	321.00	6.02	32.50	3.38	24.75	4.11	25.25	2.14	15.50	0.90	7.00
Total crop—												
1913–14	587–10	2,309	25– 2	95	13– 9	54	2–15	14	21– 2	124	.....	......
1914–15	714– 0	2,802	28– 3	119	11–15	61	12– 1	62	4– 0	17	13–15	62
1915–16	375–14	1,559	102–12	418	27–14	149	35–15	186	12– 2	70	6–13	36
1916–17	542– 0	2,307	13– 3	62	10– 0	40	4–14	20	15– 5	62	15– 8	69
Average	**554.88**	**2,244.25**	**42.31**	**173.50**	**15.84**	**76.00**	**13.95**	**70.50**	**13.14**	**68.25**	**12.08**	**55.67**
Variable fruits—												
1913–14	......	431	......	18	.....	3	.....	0	......	0	.....	......
1914–15	......	320	......	24	.....	3	.....	2	......	1	.....	2
1915–16	......	600	......	63	.....	22	.....	4	......	0	.....	4
1916–17	......	640	......	39	.....	10	.....	8	......	5	.....	22
Average	......	497.75	......	36.00	.....	9.50	.....	3.50	......	1.50	.....	9.33
Average seeds per fruit—												
1913–14	......	3.90	......	0	.....	5	.....	2	......	1	.....	......
1914–15	......	6.00	......	3	.....	3	.....	6	......	4	.....	6
1915–16	......	5.71	......	5	.....	5	.....	4	......	6	.....	6
Average	......	5.25	......	2.78	.....	4.33	.....	4.22	......	3.75	.....	6.17
50. Open strain:												
Green grade—												
1913–14	411–13	1,552	10– 6	36	10– 6	42	3–13	17	4– 0	17	.....	......
1914–15	411–10	1,540	18– 4	77	4– 1	19	2– 1	9	5– 9	23	10–10	41
1915–16	280– 7	1,013	35–15	140	19– 1	74	0–12	3	1– 4	5	1– 6	5
1916–17	324–11	1,242	14–15	612	0–12	11	4–12	17	5– 4	18	2–13	12
Average	357.14	1,336.75	19.87	78.50	9.06	36.50	2.84	11.50	4.01	15.75	4.94	19.33
Tree-Ripe grade—												
1913–14	86– 6	375	1– 4	6	1–11	9	2– 0	13	5–11	33	.....	......
1914–15	232– 3	1,014	7– 7	36	1– 0	6	5–15	30	1– 7	8	0–14	4
1915–16	73–12	363	13–12	57	11–10	58	6–10	33	11–12	70	0–13	5
1916–17	94–11	446	4–14	28	1– 2	7	0– 4	2	14– 5	62	7– 3	35
Average	121.75	549.50	6.83	31.75	3.86	20.00	3.70	19.50	8.30	43.25	2.96	14.67
Cull grade—												
1913–14	19– 6	149	0– 6	3	1– 2	6	1– 2	9	6– 4	54	.....	......
1914–15	45– 0	265	4– 4	27	2–13	21	1– 9	11	0– 8	4	0–12	5
1915–16	53– 6	325	17– 9	108	11–13	62	10– 6	64	1– 0	9	1– 8	14
1916–17	102– 3	685	2– 8	13	0– 5	2	1– 4	8	0–14	7	1– 3	9
Average	54.98	356.00	6.17	37.75	4.02	22.75	3.58	23.00	2.16	18.50	1.15	9.33

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
......	4	......	3	......	3	......	6	......	......	......	4	......	2
......	8	......	5	......	3	......	8	......	......	......	7	......	6
......	6	......	8	......	5	......	3	......	3	......	10	......	3
......	5.89	......	5.56	......	3.78	......	6.38	......	3.00	......	7.11	......	3.78
25- 0	94	85- 6	336	176- 8	632	92- 9	356	......	......	64- 5	246	21- 6	84
26- 3	96	24-12	94	73- 2	257	62- 0	231	......	......	151- 4	534	81- 0	288
9-14	34	25- 0	91	36-12	133	27- 9	94	34- 8	118	21-14	76	9- 3	32
22-13	89	12- 8	49	90- 2	335	83-15	305	......	......	112- 9	410	0- 0	0
16.78	62.60	36.91	142.50	94.13	339.25	66.52	246.50	34.50	118.00	50.00	180.86	27.89	101.00
5- 6	30	4- 9	19	15- 3	57	13- 0	54	......	......	9- 6	41	3-12	16
14- 2	53	30- 0	120	28- 3	109	36- 3	145	......	......	52-14	232	32- 2	138
0- 6	2	0-15	5	1- 0	5	0- 0	0	4- 5	17	7- 4	30	1- 9	8
1- 8	7	2- 0	10	14- 0	53	16-13	69	......	......	34-11	152	0- 0	0
4.28	18.40	9.38	38.50	14.59	56.00	16.50	67.00	4.31	17.00	14.88	65.00	9.36	40.50
0- 6	4	0-12	3	2-12	16	1- 7	10	......	......	3- 0	22	0- 3	2
0- 8	3	1-15	12	6-12	35	5- 6	30	......	......	13- 0	79	4- 8	25
0- 0	0	1-11	9	3- 2	18	0- 6	3	2- 3	11	1- 4	7	1- 9	7
0-15	8	1- 4	8	23- 5	157	4- 8	32	......	......	37- 0	189	25- 3	181
0.36	3.00	1.41	8.00	8.98	56.50	2.92	18.75	2.18	11.00	7.75	42.43	7.86	53.75
30-12	128	90-11	358	194- 7	705	107- 0	420	......	......	76-11	309	25- 5	102
40-13	152	56-11	226	108- 1	401	103- 9	406	......	......	217- 2	845	117-10	451
10- 4	36	27-10	105	40-14	156	27-15	97	41- 0	146	30- 6	113	12- 5	47
25- 4	104	15-12	67	127- 7	545	105- 4	406	......	......	184- 4	751	25- 3	181
21.41	**84.00**	**47.69**	**189.00**	**117.70**	**451.75**	**85.94**	**332.25**	**41.00**	**146.00**	**72.63**	**288.28**	**45.11**	**195.25**
......	8	......	74	......	136	......	157	......	......	......	23	......	12
......	15	......	15	......	59	......	35	......	......	......	102	......	62
......	29	......	84	......	119	......	81	......	95	......	68	......	31
......	38	......	25	......	152	......	196	......	......	......	145	......	0
......	18.00	......	49.50	......	116.50	......	117.25	......	95.00	......	48.29	......	26.25
......	6	......	8	......	4	......	5	......	......	......	3	......	4
......	6	......	6	......	10	......	5	......	......	......	7	......	8
......	6	......	7	......	8	......	6	......	5	......	5	......	5
......	5.88	......	7.11	......	7.44	......	5.33	......	5.00	......	5.22	......	5.78
6- 4	24	55-15	220	147-10	529	59- 4	229	......	......	84-11	322	29- 8	116
9- 5	34	55- 2	211	57-13	209	64-12	241	99- 1	366	......	......	85- 0	310
14- 1	47	37- 7	135	30- 3	112	41-13	145	40- 2	141	36- 4	127	22- 3	79
10- 5	41	8-15	35	58- 0	226	79- 1	296	......	......	137-14	525	0- 0	0
7.99	29.20	39.36	150.25	73.41	269.00	61.22	227.75	69.59	253.50	51.76	194.80	34.17	126.25
0- 0	0	4-12	21	34-12	137	3- 4	14	......	......	21-10	92	11- 6	50
7- 6	28	28- 3	116	13-10	55	52- 3	205	88- 2	408	......	......	26- 0	118
8-13	41	5-10	34	2- 4	12	0- 0	0	1- 3	5	4-13	20	6- 8	28
1-10	8	1-12	9	4- 6	18	7- 1	29	......	......	49- 6	236	2-12	12
3.56	15.40	10.08	45.00	13.75	55.50	15.63	62.00	44.65	206.50	15.16	69.60	11.66	52.00
0- 5	3	0-15	7	3- 9	26	2-10	20	......	......	1-12	13	1- 5	8
0-10	5	2- 9	15	6- 0	28	8- 3	44	12-14	70	......	......	4-14	35
1-13	10	0-14	8	2- 2	14	0-12	5	2- 0	11	1- 1	8	2- 8	12
1- 8	11	3- 0	24	22- 9	168	11-12	82	......	......	41- 6	231	15-14	130
0.85	5.80	1.84	13.50	8.56	59.00	5.83	37.75	7.44	40.50	8.84	50.40	6.14	46.25

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
50. Open strain—Contd.												
Total crop—												
1913–14	517– 9	2,076	12– 0	45	13– 3	57	6–15	39	15–15	104	......	......
1914–15	688–13	2,819	29–15	140	7–14	46	9– 9	50	7– 8	35	12– 4	50
1915–16	407– 9	1,701	67– 4	305	42– 8	194	17–12	100	14– 0	84	3–11	24
1916–17	521– 9	2,373	22– 5	102	4– 3	20	6– 4	27	20– 7	87	11– 3	56
Average	**533.88**	**2,242.25**	**32.88**	**148.00**	**16.94**	**79.25**	**10.12**	**54.00**	**14.47**	**77.50**	**9.04**	**43.33**
Variable fruits—												
1913–14	......	250	......	0	......	0	......	0	......	0	......	......
1914–15	......	226	......	23	......	2	......	2	......	0	......	1
1915–16	......	703	......	31	......	14	......	1	......	0	......	1
1916–17	......	573	......	53	......	7	......	3	......	8	......	5
Average	......	438.00	......	26.75	......	5.75	......	1.50	......	2.00	......	2.33
Average seeds per fruit—												
1913–14	......	4.07	......	6	......	4	......	2	......	2	......	......
1914–15	......	5.30	......	3	......	4	......	4	......	2	......	4
1915–16	......	5.31	......	8	......	9	......	6	......	6	......	6
Average	......	4.94	......	5.78	......	5.44	......	4.11	......	3.44	......	5.00
57. Bull strain:												
Green grade—												
1914–15	620– 8	2,201	1– 8	6	......	(1)	29–15	113	120– 2	422	57– 0	199
1915–16	419–10	1,537	9– 1	33	3–15	15	2– 1	7	3– 0	11	17– 7	61
1916–17	321– 9	1,132	7– 6	28	1– 1	4	3–11	12	31– 6	107	49– 4	170
Average	453.89	1,623.33	5.97	22.33	2.50	9.50	11.89	44.00	51.50	180.00	41.23	143.33
Tree-Ripe grade—												
1914–15	55– 8	219	0– 6	2	......	(1)	0– 6	2	0– 3	1	0– 3	1
1915–16	69– 4	322	1– 4	5	2– 8	14	4– 4	23	1– 7	7	0– 7	2
1916–17	28–10	130	4– 6	25	2– 2	14	1– 0	5	0– 6	2	0– 8	2
Average	51.12	223.66	2.00	10.67	2.31	14.00	1.87	10.00	0.67	3.33	0.38	1.67
Cull grade—												
1914–15	7–12	47	0– 2	1	......	(1)	0– 9	4	0– 8	3	0– 0	0
1915–16	18–15	115	0–12	4	1– 4	7	0–13	7	0– 0	0	0– 0	0
1916–17	32–13	200	1– 8	11	1– 8	9	0–13	6	0– 0	0	0– 0	0
Average	19.83	120.66	0.79	5.33	1.38	8.00	0.17	5.67	0.17	1.00	0	0
Total crop—												
1914–15	683–12	2,467	2– 0	9	......	(1)	30–14	119	120–13	426	57– 3	200
1915–16	507–13	1,974	11– 1	42	7–11	36	7– 2	37	4– 7	18	17–14	63
1916–17	383– 0	1,462	13– 4	64	4–11	27	5– 8	23	31–12	109	49–12	172
Average	**524.85**	**1,967.67**	**8.77**	**38.33**	**6.19**	**31.50**	**14.50**	**59.67**	**52.33**	**184.33**	**41.60**	**145.00**
Variable fruits—												
1914–15	......	786	......	7	......	(1)	......	47	......	127	......	53
1915–16	......	1,251	......	15	......	0	......	3	......	5	......	40
1916–17	......	795	......	28	......	5	......	8	......	71	......	120
Average	......	944.00	......	16.67	......	1.67	......	19.33	......	67.67	......	71.00
Average seeds per fruit—												
1914–15	......	2.89	......	3	......	(1)	......	4	......	1	......	0
1915–16	......	3.39	......	8	......	0	......	3	......	6	......	6
Average	......	3.15	......	5.83	......	0	......	3.83	......	3.50	......	3.25
59. Open strain:												
Green grade—												
1913–14	483–11	1,817	22– 7	83	15– 7	59	3–11	13	4– 8	18	......	......
1914–15	481– 4	1,728	23– 5	94	1– 6	6	1–11	7	14–12	56	29– 1	105
1915–16	257– 7	926	44–10	157	17– 0	65	6–15	27	5–12	21	4– 6	16
1916–17	243– 1	930	10–14	44	6–11	25	0– 9	2	4– 2	13	6–15	27
Average	366.36	1,350.25	25.31	94.50	10.13	38.75	3.22	12.25	7.28	27.00	13.46	49.33

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[1] Fruit picked in August was carried away without being recorded.

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
6– 9	27	61–10	248	185–15	692	65– 2	263	......	......	108– 1	427	42– 3	174
17– 5	67	85–14	342	77– 7	292	125– 2	490	200– 1	844	......	......	115–14	463
24–11	98	43–15	177	34– 9	138	42– 9	150	43– 5	157	42– 2	155	31– 3	119
13– 7	60	13–11	68	84–15	412	97–14	407	......	......	228–10	992	18–10	142
12.40	**50.40**	**51.28**	**208.75**	**95.72**	**383.50**	**82.67**	**327.50**	**121.68**	**500.50**	**75.76**	**314.80**	**51.97**	**224.50**
......	2	......	38	......	106	......	59	......	......	......	31	......	14
......	3	......	17	......	16	......	37	......	76	......	......	......	49
......	24	......	95	......	96	......	130	......	115	......	106	......	90
......	21	......	14	......	99	......	172	......	......	......	188	......	3
......	10.00	......	41.00	......	79.25	......	99.50	......	95.50	......	65.00	......	31.20
......	3	......	4	......	5	......	7	......	......	......	5	......	3
......	9	......	7	......	4	......	6	......	6	......	......	......	7
......	4	......	3	......	3	......	6	......	6	......	4	......	2
......	5.75	......	4.89	......	4.22	......	6.12	......	6.33	......	4.50	......	4.22
89– 7	314	107– 0	392	47– 3	167	78–11	278	45–14	160	......	......	43–12	150
52–13	185	83– 4	331	54– 9	212	61– 5	220	78–15	276	22– 2	77	31– 2	109
61–10	220	31– 9	115	55–14	199	45– 5	159	......	......	......	......	34– 7	118
67.96	239.67	73.94	279.33	52.54	192.67	61.77	219.00	62.41	218.00	22.13	77.00	18.22	62.83
8–10	31	13– 1	50	4–10	17	9– 8	37	13– 8	56	......	......	5– 1	22
1–10	8	2–12	15	6–10	36	0– 6	2	6– 3	23	12–11	52	29– 2	135
1–13	7	3–13	15	1– 6	5	2– 9	10	......	......	......	......	10–11	45
4.02	15.33	6.54	26.67	4.21	19.33	4.15	16.33	9.84	39.50	12.69	52.00	7.48	33.67
1–14	10	0– 8	2	1– 6	8	0– 9	3	1–14	14	......	......	0– 6	2
1– 0	7	0–10	3	2– 8	14	2– 2	13	4– 4	26	3–14	22	1–12	12
0– 3	1	2– 6	13	20–12	126	1– 7	11	......	......	......	......	4– 4	23
1.02	6.00	1.17	6.00	8.21	49.33	1.37	9.00	3.06	20.00	3.88	22.00	1.06	6.17
99–15	355	120– 9	444	53– 3	192	88–12	318	61– 4	230	......	......	49– 3	174
55– 7	200	86–10	349	63–11	262	63–13	235	89– 6	325	38–11	151	62– 0	256
63–10	228	37–12	143	78– 0	330	49– 5	180	......	......	......	......	49– 6	186
73.00	**261.00**	**81.64**	**312.00**	**64.96**	**261.33**	**67.29**	**244.33**	**75.31**	**277.50**	**38.69**	**151.00**	**26.76**	**102.67**
......	108	......	153	......	73	......	97	......	71	......	......	......	50
......	145	......	250	......	183	......	202	......	202	......	78	......	128
......	162	......	91	......	130	......	123	......	......	......	......	......	57
......	138.33	......	164.67	......	128.67	......	140.67	......	136.50	......	78.00	......	39.17
......	2	......	3	......	3	......	5	......	4	......	......	......	2
......	1	......	5	......	1	......	2	......	0	......	1	......	4
......	1.50	......	4.00	......	1.83	......	3.67	......	2.33	......	1.33	......	2.83
13–10	52	76–13	300	150– 5	549	93– 3	346	......	......	76– 5	289	27– 6	108
22–12	81	45– 7	168	63– 3	220	75– 0	276	......	......	138–14	483	65–13	232
22–12	76	35– 5	132	27– 3	103	38–10	135	28– 7	102	11– 2	39	15– 5	53
16– 2	62	4– 2	16	51– 6	185	57– 2	240	......	......	84–13	315	0– 5	1
15.05	54.20	40.42	154.00	73.02	264.25	65.98	249.25	28.44	102.00	44.45	160.86	27.20	98.50

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
59. Open strain—Contd.												
Tree-Ripe grade—												
1913–14	77- 2	344	1- 0	5	1-15	9	1-14	12	9-10	53	.....	.....
1914–15	190- 7	778	5- 8	28	0-12	5	3-10	20	0- 4	1	4- 0	19
1915–16	103-13	476	20- 7	81	7- 5	33	23- 2	106	14- 1	83	1- 3	7
1916–17	73- 9	313	2- 4	13	0- 5	2	0- 3	1	7- 5	30	1- 9	8
Average	111.23	477.75	7.30	31.75	2.58	12.25	7.20	34.75	7.81	41.75	2.25	11.33
Cull grade—												
1913–14	15-10	111	0- 4	1	0- 8	4	0-14	8	8- 7	57	.....	.....
1914–15	27- 2	151	2- 9	16	3- 2	21	0- 7	2	0- 6	2	0- 2	1
1915–16	48- 3	264	11- 6	55	10- 4	52	11- 6	70	0-10	4	1- 3	9
1916–17	88-10	571	0- 9	3	0- 0	0	0- 6	3	0- 3	1	0- 7	3
Average	44.89	274.25	3.69	18.75	3.47	19.25	3.27	20.75	2.41	16.00	0.58	4.33
Total crop—												
1913–14	576- 7	2,272	23-11	89	17-14	72	6- 7	33	22- 9	128	.....	.....
1914–15	698-13	2,657	31- 6	138	5- 4	32	5-12	29	15- 6	59	33- 3	125
1915–16	409- 7	1,666	76- 7	293	34- 9	150	41- 7	203	20- 7	108	6-12	32
1916–17	405- 4	1,814	13-11	60	7- 0	27	1- 2	6	11-10	44	8-15	38
Average	**522.48**	**2,102.25**	**36.30**	**145.00**	**16.17**	**70.25**	**13.69**	**67.75**	**17.50**	**84.75**	**16.29**	**65.00**
Variable fruits—												
1913–14	.....	363	.....	6	.....	2	.....	0	.....	0	.....	.....
1914–15	.....	270	.....	36	.....	0	.....	1	.....	1	.....	13
1915–16	.....	631	.....	42	.....	6	.....	19	.....	3	.....	7
1916–17	.....	549	.....	31	.....	5	.....	3	.....	0	.....	11
Average	.....	453.25	.....	28.75	.....	3.25	.....	5.75	.....	1.00	.....	10.33
Average seeds per fruit—												
1913–14	.....	3.00	.....	1	.....	2	.....	2	.....	1	.....	.....
1914–15	.....	5.91	.....	5	.....	4	.....	4	.....	6	.....	4
1915–16	.....	4.71	.....	8	.....	7	.....	6	.....	4	.....	5
Average	.....	4.33	.....	5.12	.....	4.22	.....	4.11	.....	4.00	.....	4.50
67. Open strain:												
Green grade—												
1913–14	387- 4	1,446	20-15	71	12- 0	50	1-14	8	8-12	36	.....	.....
1914–15	342- 8	1,256	13- 0	55	3- 6	15	2-11	11	4- 7	18	2- 7	9
1915–16	228- 5	833	52- 3	194	19-12	78	2- 9	10	3- 5	13	1- 8	6
1916–17	293- 7	1,085	12- 4	50	3- 3	12	4-14	18	3- 0	11	3- 6	13
Average	312.88	1,155.00	24.59	92.50	9.58	38.75	3.00	11.75	4.88	19.50	2.44	9.33
Tree-Ripe grade—												
1913–14	108-14	489	1-15	9	0- 9	4	1- 0	6	11-10	68	.....	.....
1914–15	196-15	859	5-11	28	1-10	10	4- 8	27	0-10	4	2- 6	14
1915–16	85- 7	413	17-10	72	16- 5	73	22- 9	116	5-12	34	4-12	27
1916–17	106- 0	469	4- 6	24	0-11	4	0- 0	0	8- 2	36	3- 1	13
Average	124.31	557.50	7.41	33.25	4.80	22.75	7.01	37.25	6.53	35.50	3.40	18.00
Cull grade—												
1913–14	18- 2	130	0- 1	1	0-10	5	0-14	7	8- 2	62	.....	.....
1914–15	64- 5	384	1- 7	9	2- 4	17	0-15	8	0- 6	3	0- 7	3
1915–16	80-15	460	27- 4	148	17-14	98	22-12	131	0-14	6	1- 0	8
1916–17	97-11	632	1-10	9	0- 2	1	0- 8	4	1- 1	7	2- 8	24
Average	65.26	401.50	7.59	41.75	5.22	30.25	6.27	37.50	2.61	19.50	1.31	11.67
Total crop—												
1913–14	514- 4	2,065	22-15	81	13- 3	59	3-12	21	28- 8	166	.....	.....
1914–15	603-12	2,499	20- 2	92	7- 4	42	8- 2	46	5- 7	25	5- 4	26
1915–16	394-11	1,706	97- 1	414	53-15	249	47-14	257	9-15	53	7- 4	41
1916–17	497- 2	2,186	18- 4	83	4- 0	17	5- 6	22	12- 3	54	8-15	50
Average	**502.45**	**2,114.00**	**39.59**	**167.50**	**19.59**	**91.75**	**16.28**	**86.50**	**14.01**	**74.50**	**7.14**	**39.00**
Variable fruits—												
1913–14	.....	192	.....	0	.....	0	.....	0	.....	1	.....	.....
1914–15	.....	181	.....	17	.....	1	.....	0	.....	1	.....	0
1915–16	.....	530	.....	29	.....	21	.....	2	.....	3	.....	1
1916–17	.....	462	.....	47	.....	2	.....	2	.....	1	.....	3
Average	.....	341.25	.....	23.25	.....	6.00	.....	1.00	.....	1.50	.....	1.33

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
9- 2	51	2-10	11	27- 0	103	11- 2	45	......	......	9- 0	39	3-13	16
8- 4	31	39- 6	157	28-12	110	44- 2	170	......	......	36- 6	157	19- 7	80
9- 8	40	4- 2	22	1-12	9	0- 8	3	0- 4	1	11- 7	47	10- 2	44
0- 9	4	1- 0	5	17- 0	64	12- 6	50	......	......	31- 0	136	0- 0	0
5.49	25.20	11.78	48.75	18.63	71.50	17.03	67.00	0.25	1.00	12.54	54.14	8.34	35.00
1-11	13	0- 4	2	0- 7	3	1- 3	9	......	......	1-12	12	0- 4	2
0- 4	1	2- 1	8	5- 0	29	3- 4	17	......	......	7-15	41	2- 0	13
0- 2	1	0- 0	0	5-13	34	0-15	5	2-11	14	3- 8	18	0- 5	2
0- 4	2	0-11	6	15- 0	109	3- 2	21	......	......	40- 0	211	28- 0	212
0.46	3.40	0.75	4.00	6.56	43.75	2.13	13.00	2.69	14.00	7.60	40.29	7.64	57.25
24- 7	116	79-11	313	177-12	655	105- 8	400	......	......	87- 1	340	31- 7	126
31- 4	113	86-14	333	96-15	359	122- 6	463	......	......	183- 3	681	87- 4	325
32- 6	117	39- 7	154	34-12	146	40- 1	143	31- 6	117	26- 1	104	25-12	99
16-15	68	5-13	27	83- 6	358	72-10	311	......	......	155-13	662	28- 5	213
21.00	**82.80**	**52.95**	**206.75**	**98.20**	**379.50**	**85.14**	**329.25**	**31.38**	**117.00**	**64.59**	**255.29**	**43.19**	**190.75**
......	3	......	54	......	102	......	134	......	......	......	53	......	9
......	9	......	7	......	24	......	54	......	......	......	84	......	41
......	61	......	115	......	85	......	114	......	84	......	40	......	55
......	30	......	4	......	149	......	162	......	......	......	154	......	0
......	20.60	......	45.00	......	90.00	......	116.00	......	84.00	......	47.29	......	26.25
......	4	......	4	......	6	......	2	......	......	......	3	......	4
......	3	......	4	......	4	......	5	......	......	......	8	......	8
......	2	......	2	......	1	......	4	......	5	......	6	......	4
......	2.89	......	3.50	......	3.89	......	4.00	......	5.33	......	5.67	......	5.44
8-4	30	51- 6	199	128- 2	460	66- 6	253	......	......	62- 2	231	27- 7	108
8-4	30	27- 7	105	53-10	190	57-12	210	......	......	100- 8	359	69- 0	254
5-1	18	18- 7	69	29- 4	108	26-12	96	31-13	109	23-15	83	13-12	49
16-7	62	14- 3	55	46-13	172	81-13	292	......	......	107- 8	400	0- 0	0
7.60	28.00	27.86	107.00	64.45	232.50	58.17	212.75	31.81	109.00	42.01	153.29	27.55	102.75
2-15	19	8- 3	34	27- 8	109	14-14	64	......	......	30- 2	131	10- 2	45
3- 4	12	21- 0	87	23- 0	89	24- 0	96	......	......	69- 9	308	41- 5	184
2-13	13	5-12	35	0-12	5	0- 4	2	1-12	7	3-15	16	3- 3	13
2- 5	11	2-13	12	10-14	42	28- 1	113	......	......	45-11	214	0- 0	0
2.26	11.00	9.44	42.00	15.53	61.25	16.80	68.75	1.75	7.00	21.33	95.57	13.66	60.50
0-13	6	0-12	5	1-12	13	2- 6	14	......	......	2-4	14	0- 8	3
0- 3	1	1- 6	8	7-14	43	8- 2	47	......	......	30-5	177	11- 0	68
0- 4	2	1- 5	10	3- 9	22	0-12	6	2-9	13	2-2	13	0-10	3
1- 9	12	2- 4	15	20- 0	136	3- 8	26	......	......	41-4	225	23- 5	173
0.56	4.20	1.42	9.50	8.30	53.50	3.69	23.25	2.56	13.00	10.85	61.28	8.86	61.75
12- 0	55	60- 5	238	157- 6	582	83-10	331	......	......	94-8	376	38- 1	156
11-11	43	49-13	200	84- 8	322	89-14	353	......	......	200-6	844	121- 5	506
8- 2	33	25- 8	114	33- 9	135	27-12	104	36-2	129	30-0	112	17- 9	65
20- 5	85	19- 4	82	77-11	350	113- 6	431	......	......	194-7	839	23- 5	173
10.42	**43.20**	**38.72**	**158.50**	**88.29**	**347.25**	**78.66**	**304.75**	**36.13**	**129.00**	**74.18**	**310.14**	**50.07**	**225.00**
......	5	......	27	......	59	......	69	......	......	......	22	......	9
......	5	......	17	......	17	......	23	......	......	......	60	......	40
......	14	......	61	......	96	......	79	......	98	......	76	......	50
......	24	......	11	......	74	......	164	......	......	......	134	......	0
......	9.60	......	29.00	......	61.50	......	83.75	......	98.00	......	41.71	......	24.75

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
67. Open strain—Contd.												
Average seeds per fruit—												
1913–14	......	3.67	......	2	.....	2	.....	3	......	2	.....	......
1914–15	......	4.64	......	4	.....	4	.....	3	......	2	.....	3
1915–16	......	5.33	......	8	.....	5	.....	7	......	5	.....	6
Average	......	4.60	......	4.78	.....	3.78	.....	4.11	......	3.22	.....	4.33
75. Open strain:												
Green grade—												
1913–14	488–13	1,813	20–13	68	20–15	84	0– 8	2	8– 8	34	.....	......
1914–15	388– 5	1,399	13– 4	54	6–10	29	1– 8	6	15– 5	58	8– 1	30
1915–16	204– 5	785	80–10	335	19– 2	74	3–13	15	0–13	3	0– 9	2
1916–17	199– 4	744	17–10	68	2– 0	8	2– 1	8	2– 3	8	0– 0	0
Average	320.17	1,185.25	33.08	131.25	12.17	48.75	1.97	7.75	6.70	25.75	2.87	10.67
Tree-Ripe grade—												
1913–14	60– 5	272	0–14	4	1– 4	7	2–10	16	8– 1	42	.....	......
1914–15	150– 6	638	4– 9	22	1– 1	6	2– 1	12	1– 0	6	2– 3	11
1915–16	94– 0	434	32– 2	135	13– 2	63	21– 4	103	5– 6	33	1– 8	11
1916–17	81–11	367	7– 3	37	2– 0	13	0–10	3	8– 3	37	1–12	8
Average	96.59	427.75	11.19	49.50	4.36	22.25	6.64	33.50	5.66	29.50	1.81	10.00
Cull grade—												
1913–14	18–10	136	0– 8	4	0– 7	4	0– 8	4	12– 8	91	.....	......
1914–15	44–13	259	1–12	11	4– 5	26	2– 1	13	0– 4	2	0– 8	4
1915–16	70– 7	402	24– 6	126	14– 3	78	17– 2	108	1– 2	8	0–12	6
1916–17	119–12	841	3–10	18	0– 8	4	0–10	5	0– 6	3	0–13	9
Average	63.40	409.50	7.56	39.75	4.86	28.00	5.08	32.50	3.56	26.00	0.69	6.33
Total crop—												
1913–14	567–12	2,221	22– 3	76	22–10	95	3–10	22	29– 1	167	.....	......
1914–15	583– 8	2,296	19– 9	87	12– 0	61	5–10	31	16– 9	66	10–12	45
1915–16	368–12	1,621	137– 2	596	46– 7	215	42– 3	226	7– 5	44	2–13	19
1916–17	400–11	1,952	28– 7	123	4– 8	25	3– 5	16	10–12	48	2– 9	17
Average	**480.17**	**2,022.50**	**51.83**	**220.50**	**21.39**	**99.00**	**13.69**	**73.75**	**15.92**	**81.25**	**5.37**	**27.00**
Variable fruits—												
1913–14	......	369	......	10	.....	0	.....	0	......	0	.....	......
1914–15	......	207	......	15	.....	3	.....	0	......	1	.....	1
1915–16	......	401	......	58	.....	15	.....	7	......	0	.....	1
1916–17	......	417	......	71	.....	5	.....	1	......	9	.....	1
Average	......	348.50		38.50	.....	5.75	.....	2.00	......	2.50	.....	1.00
Average seeds per fruit—												
1913–14	......	3.62	......	4	.....	3	.....	3	......	2	.....	......
1914–15	......	4.12	......	3	.....	4	.....	3	......	1	.....	5
1915–16	......	6.17	......	9	.....	8	.....	6	......	6	.....	5
Average	......	4.71	......	5.33	.....	5.22	.....	3.78	......	2.89	.....	5.00
76. Lisbon strain:												
Green grade—												
1913–14	454– 0	1,689	23– 3	80	12–12	52	2–10	10	9–12	41	.....	......
1914–15	465– 6	1,670	17–14	73	5–10	25	1– 7	6	12–15	50	18– 4	66
1915–16	234–14	846	45– 9	168	17–13	73	2– 4	9	4– 4	16	1– 1	4
1916–17	247– 6	921	7–15	35	3– 0	12	2– 6	9	4– 0	15	3–11	15
Average	350.41	1,281.50	23.64	89.00	9.80	40.50	2.17	8.50	7.73	30.50	7.67	28.33
Tree-Ripe grade—												
1913–14	56–10	264	1–10	7	1– 1	6	2–14	17	6–10	38	.....	......
1914–15	166– 3	699	3– 0	15	0– 9	4	1– 3	6	1– 0	5	6– 1	42
1915–16	64–11	297	13–14	56	13–11	62	8–11	44	4–14	30	1–13	11
1916–17	83– 3	370	0–12	4	0– 8	3	0– 0	0	5– 0	22	2– 8	14
Average	92.67	407.50	4.81	20.50	3.95	18.75	3.19	16.75	4.38	23.75	3.46	22.33
Cull grade—												
1913–14	11– 8	81	0– 9	3	0– 7	2	0–10	5	3–12	30	.....	......
1914–15	27–11	151	1– 3	8	3– 7	22	0– 4	2	0– 7	3	0– 2	1
1915–16	43– 0	230	12– 7	59	10–11	56	6– 5	38	0–15	9	0– 5	3
1916–17	62–13	441	1– 4	6	0– 0	0	0– 0	0	0– 0	0	1– 2	14
Average	36.25	225.75	3.86	19.00	3.64	20.00	1.80	11.25	1.28	10.50	0.52	6.00

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
......	5	......	4	......	3	......	8	......	......	......	2	......	4
......	3	......	3	......	6	......	6	......	......	......	5	......	11
......	5	......	5	......	4	......	4	......	3	......	9	......	4
......	4.33	......	4.22	......	4.56	......	6.00	......	3.00	......	5.22	......	6.44
12- 1	45	54- 3	209	187-15	679	93-12	352	......	......	63- 3	237	26-15	103
31-11	111	35- 6	133	60- 8	214	44- 6	161	......	......	118-11	414	52-15	189
3- 7	12	16- 8	62	11-14	45	18- 1	63	22-13	79	10- 9	37	16- 2	58
5- 5	20	2-13	11	20-14	77	41- 2	149	......	......	105- 0	394	0- 4	1
10.50	37.60	27.22	103.75	70.30	253.75	49.33	181.25	22.81	79.00	42.49	154.57	24.06	87.75
7-10	40	5- 4	21	8- 7	31	7- 1	29	......	......	14-12	63	4- 6	19
7-11	29	23- 9	95	15- 6	59	19- 8	77	......	......	43- 1	187	30- 5	134
2- 1	9	1- 2	7	1- 2	6	0- 0	0	2-5	9	9- 0	36	5- 0	22
0- 3	1	1- 0	5	7- 9	28	21-11	90	......	......	31- 8	145	0- 0	0
3.51	15.80	7.73	32.00	8.12	31.00	12.06	49.00	2.31	9.00	14.05	61.57	9.92	43.75
1- 6	8	0- 0	0	0-10	3	0-13	6	......	......	1- 8	13	0- 6	3
0- 4	1	1-13	9	3- 5	18	5-10	32	......	......	15-12	92	9- 3	51
0- 3	2	0- 8	4	5- 2	29	1- 0	6	1-12	11	2-12	15	1- 9	9
1- 0	8	2- 6	19	26- 4	204	9- 6	71	......	......	49- 0	283	25-13	217
0.56	3.80	1.17	8.00	8.83	63.50	4.20	28.75	1.75	11.00	9.87	57.57	9.23	70.00
21- 1	93	59- 7	230	197- 0	713	101-10	387	......	......	79- 7	313	31-11	125
39-10	141	60-12	237	79- 3	291	69- 8	270	......	......	177- 8	693	92- 7	374
5-11	23	18- 2	73	18- 2	80	19- 1	69	26-14	99	22- 5	88	22-11	89
6- 8	29	6- 3	35	54-11	309	72- 3	310	......	......	185- 8	822	26- 1	218
14.57	**57.20**	**36.12**	**143.75**	**87.25**	**348.25**	**65.59**	**259.00**	**26.88**	**99.00**	**66.39**	**273.71**	**43.22**	**201.50**
......	1	......	87	......	126	......	90	......	......	......	38	......	17
......	10	......	10	......	13	......	19	......	......	......	99	......	36
......	9	......	52	......	43	......	61	......	54	......	45	......	56
......	11	......	7	......	49	......	138	......	......	......	125	......	0
......	6.20	......	39.00	......	57.75	......	77.00	......	54.00	......	43.86	......	27.25
......	2	......	3	......	5	......	4	......	......	......	4	......	6
......	2	......	4	......	4	......	5	......	......	......	8	......	6
......	7	......	6	......	6	......	7	......	6	......	3	......	5
......	3.67	......	4.63	......	5.11	......	5.25	......	5.67	......	5.11	......	5.67
16- 7	63	61- 9	243	95- 7	344	137- 6	495	......	......	71- 5	269	23- 9	92
24- 8	89	46-13	177	41- 9	146	62- 2	226	......	......	136-11	465	97- 9	347
16- 5	50	31-11	116	22- 0	83	38- 0	128	26- 0	92	18- 3	66	11-12	41
16-14	67	12-12	50	51-15	190	63-10	226	......	......	80- 3	298	1- 0	4
14.83	53.80	38.20	146.50	52.73	190.75	75.28	268.75	26.00	92.00	43.77	156.86	33.47	121.00
7- 4	45	0- 8	2	14- 6	54	12- 0	48	......	......	9- 3	42	1- 2	5
10-12	41	21- 6	87	22-14	87	25-13	100	......	......	48-14	207	24-11	105
1-14	9	1- 6	9	1- 0	5	0- 0	0	2-10	10	7-10	31	7- 4	30
0- 8	2	2-12	11	15- 0	58	13-10	52	......	......	36- 0	164	6- 9	40
4.08	19.40	6.50	27.25	13.31	51.00	12.86	50.00	2.63	10.00	14.53	63.43	9.91	45.00
0- 4	3	0-12	5	1- 1	6	2- 3	13	......	......	1-12	13	0- 2	1
0- 2	1	2- 1	14	4- 2	21	4- 4	21	......	......	6-11	34	5- 0	24
0- 6	2	0-12	6	2- 8	15	2- 4	11	2-13	14	2- 2	10	1- 8	7
0-11	6	3- 2	25	20-10	138	7- 2	49	......	......	21- 0	128	7-14	75
0.29	2.40	1.67	12.50	7.08	45.00	3.95	23.50	2.81	14.00	4.51	26.43	3.63	26.75

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
76. Lisbon strain—Contd.												
Total crop—												
1913–14	522– 2	2,034	25– 6	90	14– 4	60	6– 2	32	20– 2	109	......	......
1914–15	659– 4	2,520	22– 1	96	9–10	51	2–14	14	14– 6	58	24– 7	109
1915–16	342– 9	1,373	71–14	283	42– 3	191	17– 4	91	10– 1	55	3– 3	18
1916–17	393– 6	1,732	9–15	45	3– 8	15	2– 6	9	9– 0	37	7– 5	43
Average	**479.33**	**1,914.75**	**32.31**	**128.50**	**17.39**	**79.25**	**7.16**	**36.50**	**13.39**	**64.75**	**11.65**	**56.67**
Variable fruits—												
1913–14	......	302	......	13	......	0	......	0	......	1	......	......
1914–15	......	227	......	14	......	5	......	3	......	9	......	6
1915–16	......	554	......	41	......	14	......	1	......	3	......	0
1916–17	......	467	......	23	......	7	......	1	......	8	......	6
Average	......	387.50	......	22.75	......	6.50	......	1.25	......	5.25	......	4.00
Average seeds per fruit—												
1913–14	......	3.93	......	1	......	9	......	2	......	2	......	......
1914–15	......	4.22	......	3	......	3	......	7	......	3	......	4
1915–16	......	5.44	......	8	......	6	......	6	......	7	......	5
Average	......	4.58	......	3.89	......	6.00	......	5.00	......	4.00	......	4.50
81. Sporting strain:												
Green grade—												
1913–14	251–13	954	8–13	34	3– 2	13	1– 8	5	32–12	131	......	......
1914–15	571– 2	2,022	7– 1	28	2– 2	8	2– 0	8	76– 3	274	......	(1)
1915–16	466–15	1,637	21– 6	75	9– 3	34	0– 9	2	4– 4	14	4–12	17
1916–17	294– 3	1,054	10–14	40	0– 0	0	1– 8	6	7– 3	24	30– 8	110
Average	396.02	1,416.75	12.03	44.25	3.61	13.75	1.39	5.25	30.09	110.75	17.63	63.50
Tree-Ripe grade—												
1913–14	23–12	106	1– 8	8	0–10	3	0–11	3	1–12	11	......	......
1914–15	75– 9	300	1– 6	8	2– 2	11	0– 7	3	0– 4	1	......	(1)
1915–16	44–11	195	6– 6	27	3– 8	16	3– 0	15	2– 6	12	3– 3	15
1916–17	68–13	272	2–13	14	0– 0	0	0– 5	2	1– 0	4	0–11	3
Average	53.20	218.25	3.02	14.25	1.56	7.50	1.11	5.75	1.34	7.00	1.94	9.00
Cull grade—												
1913–14	3– 9	31	0– 7	3	0– 6	2	0– 7	5	0– 1	1	......	......
1914–15	11– 2	61	0– 2	1	1– 6	7	1– 0	7	0– 0	0	......	(1)
1915–16	18–14	97	2– 0	10	0– 8	3	2–14	17	1– 2	7	0– 3	1
1916–17	19–10	122	1– 1	5	0– 0	0	1– 2	7	0– 5	2	0– 0	0
Average	13.30	77.75	0.91	4.75	0.56	3.00	1.36	9.00	0.38	2.50	0.09	0.50
Total crop—												
1913–14	279– 2	1,091	10–12	45	4– 2	18	2–10	13	34– 9	143	......	......
1914–15	657–13	2,383	8– 9	37	5–10	26	3– 7	18	76– 7	275	......	(1)
1915–16	530– 8	1,929	29–12	112	13– 3	53	6– 7	34	7–12	33	8– 2	33
1916–17	382–10	1,448	14–12	59	0– 0	0	2–15	15	8– 8	30	31– 3	113
Average	**462.52**	**1,712.75**	**13.95**	**63.25**	**5.73**	**24.25**	**3.86**	**20.00**	**31.81**	**120.25**	**19.65**	**73.00**
Variable fruits—												
1913–14	......	334	......	5	......	1	......	0	......	9	......	......
1914–15	......	781	......	11	......	8	......	4	......	62	......	(1)
1915–16	......	1,225	......	37	......	9	......	2	......	6	......	8
1916–17	......	928	......	32	......	0	......	1	......	20	......	66
Average	......	817.00	......	21.25	......	4.50	......	1.75	......	24.25	......	37.00
Average seeds per fruit—												
1913–14	......	4.65	......	8	......	7	......	3	......	3	......	......
1914–15	......	2.28	......	3	......	5	......	0	......	3	......	(1)
1915–16	......	2.46	......	1	......	2	......	2	......	7	......	4
Average	......	3.03	......	3.89	......	4.56	......	1.56	......	4.50	......	3.67

[1] Fruit picked in November, 1914, was removed without being recorded. In January and February,

trees of the Lisbon variety for the 6-year period from July 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
23–15	111	62–13	250	110–14	404	151– 9	556	......	......	82– 4	324	24–13	98
35– 6	131	70– 4	278	68– 9	254	92– 3	347	......	......	192– 4	706	127– 4	476
18– 9	61	33–13	131	25– 8	103	40– 4	139	31– 7	116	27–15	107	20– 8	78
18– 1	75	18–10	86	87– 9	386	84– 6	327	......	......	137– 3	590	15– 7	119
19.19	75.60	46.38	186.25	73.13	286.75	92.09	342.25	31.44	116.00	62.80	246.71	47.00	192.75
......	1	......	16	......	67	......	145	......	......	......	37	......	22
......	11	......	14	......	21	......	38	......	......	......	49	......	57
......	41	......	102	......	71	......	108	......	66	......	59	......	48
......	31	......	23	......	106	......	149	......	......	......	107	......	6
......	16.80	......	38.75	......	66.25	......	110.00	......	66.00	......	36.00	......	33.25
......	4	......	3	......	6	......	2	......	......	......	5	......	5
......	5	......	3	......	2	......	6	......	......	......	5	......	6
......	2	......	2	......	6	......	6	......	5	......	6	......	7
......	3.89	......	2.89	......	4.44	......	4.43	......	4.67	......	5.22	......	6.11
90–12	328	......	(1)	......	(1)	40– 4	159	34– 7	136	26– 9	98	13–10	50
54– 4	189	149– 8	529	49–15	177	101–12	363	65– 2	231	......	......	63– 3	215
15–12	57	100– 2	377	52– 0	196	69– 8	238	139– 6	456	24– 1	83	26– 0	88
72– 7	261	34– 2	125	61– 2	224	24–13	91	......	......	......	......	51–10	173
46.64	167.00	94.59	343.67	54.35	199.00	59.08	212.75	79.64	274.33	25.31	90.50	22.06	75.14
0– 2	1	......	(1)	......	(1)	5– 7	22	3–13	16	8– 8	36	1– 5	6
2–13	10	13–14	54	13– 0	47	13– 6	49	20–11	87	......	......	7–10	30
1–14	10	1–13	8	0–13	5	0– 0	0	2–11	10	6–15	26	12– 2	51
0– 0	0	4–13	20	1– 6	5	5–12	22	......	......	......	......	52– 1	202
0.96	4.20	6.83	27.33	5.06	19.00	6.14	23.25	9.06	37.67	7.72	31.00	10.45	41.29
0– 3	1	......	(1)	......	(1)	1– 9	15	0– 7	3	0– 0	0	0– 1	1
0–14	5	1– 0	5	2– 2	9	1– 3	5	2– 4	16	......	......	1– 3	6
0– 3	1	0– 6	2	3– 7	16	1– 1	6	2– 9	12	4– 3	20	0– 6	2
0– 0	0	1– 2	9	6– 6	37	2–10	18	......	......	......	......	7– 0	44
0.25	1.40	0.83	5.33	3.98	20.67	1.61	11.00	1.75	10.33	2.09	10.00	1.23	7.57
91– 1	330	......	(1)	......	(1)	47– 4	196	38–11	155	35– 1	134	15– 0	57
57–15	204	164– 6	588	65– 1	233	116– 5	417	88– 1	334	......	......	72– 0	251
17–13	68	102– 5	387	56– 4	217	70– 9	244	144–10	478	35– 3	129	38– 8	141
72– 7	261	40– 1	154	68–14	266	33– 3	131	......	......	......	......	110–11	419
47.85	172.60	102.25	376.33	63.39	238.67	66.83	247.00	90.46	322.33	35.13	131.50	33.74	124.00
......	121	......	(1)	......	(1)	......	84	......	60	......	38	......	16
......	108	......	181	......	74	......	134	......	107	......	......	......	92
......	35	......	301	......	162	......	201	......	332	......	63	......	69
......	232	......	105	......	191	......	101	......	......	......	......	......	180
......	99.20	......	195.67	......	142.33	......	130.00	......	166.33	......	50.50	......	51.00
......	8	......	(1)	......	(1)	......	1	......	6	......	2	......	3
......	1	......	4	......	6	......	0	......	0	......	......	......	1
......	1	......	2	......	3	......	4	......	2	......	1	......	2
......	3.33	......	2.83	......	4.50	......	1.37	......	2.67	......	1.40	......	2.22

1914, this tree was picked by mistake by the regular pickers and no record made of its crop.

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
85. Open strain:												
Green grade—												
1913–14	446–3	1,646	18–9	63	16–6	62	2–4	9	4–14	18	......	......
1914–15	436–2	1,610	8–4	34	4–6	18	2–5	10	8–4	32	28–15	106
1915–16	243–13	907	30–2	112	15–11	64	1–7	6	1–13	7	0–12	3
1916–17	126–2	494	16–2	68	1–12	7	1–0	4	0–0	0	1–5	5
Average	313.06	1,164.25	18.26	69.25	9.55	37.75	1.75	7.25	3.73	14.25	10.33	38.00
Tree-Ripe grade—												
1913–14	49–4	214	0–3	1	1–4	5	1–4	7	4–8	21	......	......
1914–15	171–12	728	9–5	45	1–8	9	2–2	12	1–0	5	0–14	5
1915–16	83–10	399	15–13	65	12–2	58	11–1	59	7–8	47	2–3	15
1916–17	93–15	450	13–8	63	0–14	5	0–3	1	4–0	17	1–3	7
Average	99.64	447.75	9.70	43.50	3.94	19.25	3.66	19.75	4.25	22.50	1.42	9.00
Cull grade—												
1913–14	14–8	93	0–7	4	0–4	2	0–12	5	6–13	41	......	......
1914–15	22–10	137	1–3	7	2–3	13	1–3	8	0–0	0	0–3	1
1915–16	50–10	299	13–5	73	11–5	62	11–9	74	1–2	9	0–8	4
1916–17	92–9	745	2–10	15	0–14	5	0–0	0	0–0	0	0–5	5
Average	45.08	318.50	4.39	24.75	3.66	20.50	3.38	21.75	1.98	12.50	0.33	3.33
Total crop—												
1913–14	509–15	1,953	19–3	68	17–14	69	4–4	21	16–3	80	......	......
1914–15	630–8	2,475	18–12	86	8–1	40	5–10	30	9–4	37	30–0	112
1915–16	378–1	1,605	59–4	250	39–2	184	24–1	139	10–7	63	3–7	22
1916–17	312–10	1,689	32–4	146	3–8	17	1–3	5	4–0	17	2–13	17
Average	**457.78**	**1,930.50**	**32.36**	**137.50**	**17.14**	**77.50**	**8.78**	**48.75**	**9.97**	**49.25**	**12.08**	**50.33**
Variable fruits—												
1913–14	......	554	......	13	......	4	......	0	......	0	......	......
1914–15	......	427	......	17	......	5	......	0	......	5	......	21
1915–16	......	671	......	26	......	16	......	3	......	0	......	1
1916–17	......	325	......	76	......	3	......	1	......	3	......	3
Average	......	494.25	......	33.00	......	7.00	......	1.00	......	2.00	......	8.33
Average seeds per fruit—												
1913–14	......	4.47	......	3	......	5	......	3	......	2	......	......
1914–15	......	4.69	......	5	......	5	......	2	......	0	......	5
1915–16	......	5.03	......	8	......	8	......	6	......	3	......	8
Average	......	4.74	......	5.56	......	6.22	......	3.56	......	1.87	......	6.50
93. Open strain:												
Green grade—												
1913–14	417–4	1,570	16–14	60	13–3	55	2–8	10	5–4	21	......	......
1914–15	229–11	838	8–4	34	5–4	22	1–10	7	2–6	9	1–7	5
1915–16	172–2	638	46–14	179	22–2	91	1–0	4	0–0	0	0–0	0
1916–17	203–10	757	13–12	55	2–13	11	7–6	29	2–11	10	3–10	14
Average	255.67	950.75	21.44	82.00	10.84	44.75	3.12	12.50	2.58	10.00	1.69	6.33
Tree-Ripe grade—												
1913–14	152–1	634	0–4	1	1–0	6	1–15	12	5–9	34	......	......
1914–15	178–9	797	4–12	24	4–11	26	5–9	32	0–0	0	0–4	1
1915–16	98–11	483	25–14	123	24–15	112	15–2	89	3–12	26	1–1	7
1916–17	89–9	404	7–10	38	2–0	13	0–9	3	11–2	48	5–14	28
Average	129.72	579.50	9.62	46.50	8.16	39.25	5.80	34.00	5.11	27.00	2.39	12.00
Cull grade—												
1913–14	27–8	187	0–4	2	0–9	4	0–12	9	9–10	70	......	......
1914–15	43–4	322	3–1	19	2–15	19	1–1	10	0–11	6	0–5	2
1915–16	68–15	431	22–7	131	14–0	84	14–7	103	0–9	5	1–0	7
1916–17	67–1	448	0–12	4	1–3	8	1–2	7	1–0	5	0–4	2
Average	51.68	347.00	6.62	39.00	4.67	28.75	4.34	32.25	2.97	21.50	0.52	3.67
Total crop—												
1913–14	596–13	2,391	17–6	63	14–12	65	5–3	31	20–7	125	......	......
1914–15	451–8	1,957	16–1	77	12–14	67	8–4	49	3–1	15	2–0	8
1915–16	339–12	1,552	95–3	433	61–1	287	30–9	196	4–5	31	2–1	14
1916–17	360–4	1,609	22–2	97	6–0	32	9–1	39	14–13	63	9–12	44
Average	**437.08**	**1,877.25**	**37.69**	**167.50**	**23.67**	**112.75**	**13.27**	**78.75**	**10.66**	**58.50**	**4.60**	**22.00**

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
16– 8	63	60– 9	237	169– 9	599	91– 1	341	......	......	46– 8	177	19–15	77
31– 6	118	50– 4	195	60–11	220	62– 6	232	......	......	120– 6	430	58–15	215
3– 0	10	27– 2	104	35– 7	138	34– 5	128	56–12	199	19– 2	70	18– 4	66
3– 1	12	1– 8	6	9– 3	35	20– 7	77	......	......	71–12	280	0– 0	0
10.79	40.60	34.86	135.50	68.72	248.00	52.05	194.50	56.75	199.00	36.82	136.71	24.28	89.50
6–10	34	5–10	23	3–13	14	9–10	40	......	......	10– 0	42	6– 6	27
7–15	31	23– 5	97	13–12	54	40– 3	159	......	......	56– 6	245	15– 6	66
2– 0	9	4– 5	27	1–15	10	0– 0	0	8–13	35	7–10	31	10– 4	43
1– 4	7	1–12	10	4– 9	18	9–15	45	......	......	56–11	277	0– 0	0
3.56	16.20	8.75	39.25	6.02	24.00	14.94	61.00	8.81	35.00	18.67	85.00	8.00	34.00
0–12	6	0– 3	1	2– 3	15	0– 9	4	......	......	2– 2	12	0– 7	3
1– 2	6	0–12	5	3– 6	21	2– 0	11	......	......	6– 2	38	4– 8	27
0– 0	0	0– 8	3	3– 9	22	0– 4	6	1–14	10	3–15	21	2–11	15
0–10	7	2– 6	22	13–10	115	3– 2	28	......	......	29– 8	189	39– 8	359
0.50	3.80	0.95	7.75	5.69	43.25	1.48	12.25	1.88	10.00	5.96	37.14	11.78	101.00
23–14	103	66– 6	261	175– 9	628	101– 4	385	......	......	58–10	231	26–12	107
40– 7	155	74– 5	297	77–13	295	104– 9	402	......	......	182–14	713	78–13	308
5– 0	19	31–15	134	40–15	170	34– 9	134	67–7	244	30–11	122	31– 3	124
4–15	26	5–10	38	27– 6	168	33– 8	150	......	......	157–15	746	39– 8	359
14.85	**60.60**	**44.56**	**182.50**	**80.42**	**315.25**	**68.47**	**267.75**	**67.44**	**244.00**	**61.45**	**258.86**	**44.06**	**224.50**
......	22	......	116	......	168	......	130	......	......	......	76	......	25
......	22	......	50	......	35	......	69	......	......	......	159	......	44
......	9	......	92	......	122	......	108	......	178	......	55	......	61
......	9	......	4	......	29	......	95	......	......	......	102	......	0
......	12.40	......	65.50	......	88.50	......	100.50	......	178.00	......	56.00	......	32.50
......	6	......	6	......	7	......	4	......	......	......	2	......	7
......	5	......	4	......	4	......	6	......	......	......	9	......	4
......	7	......	6	......	2	......	1	......	5	......	3	......	1
......	6.00	......	5.44	......	4.44	......	4.00	......	5.33	......	4.67	......	4 00
12– 8	49	55– 4	218	126–12	456	69– 3	264	......	......	95– 1	355	20–11	82
5–12	20	22–12	84	22– 2	79	34– 2	123	68– 4	242	......	......	57–12	213
1– 7	5	9– 6	35	13– 2	49	27– 9	95	25– 6	90	16– 6	58	8–14	32
10– 5	40	9– 4	35	31– 1	112	42– 2	152	......	......	77– 0	284	3–10	15
6.00	22.80	24.16	93.00	48.27	174.00	43.25	158.50	46.82	166.00	37.69	139.40	18.19	68.40
0– 8	2	11–10	49	61– 7	233	16–11	70	......	......	40– 0	173	13– 1	54
2– 3	8	7– 7	29	13– 0	50	20– 3	80	77– 5	349	......	......	43– 3	198
2– 2	9	3– 7	20	0– 8	3	0– 0	0	1– 0	4	16– 8	70	4– 6	20
1– 3	6	3– 0	13	6– 4	24	10– 0	40	......	......	37– 7	161	4– 8	30
1.20	5.00	6.38	27.75	20.30	77.50	11.72	47.50	39.16	176.50	18.79	80.80	13.03	60.40
0–10	6	1– 9	8	5– 2	35	3–12	24	......	......	4– 7	24	0–13	5
0– 0	0	1– 2	8	5– 0	33	3–12	22	12– 9	128	......	......	12–12	75
0–13	7	1– 6	10	5– 1	31	1– 1	5	4– 6	26	2– 8	14	1– 5	8
0– 9	6	2– 0	17	12–14	88	5–11	42	......	......	25–10	142	16– 0	127
0.40	3.80	1.51	10.75	7.02	46.75	3.56	23.25	8.47	77.00	6.51	36.00	6.18	43.00
13–10	57	68– 7	275	193– 5	724	89–10	358	......	......	139–8	552	34– 9	141
7–15	28	31– 5	121	40– 2	162	58– 1	225	158– 2	719	......	......	113–11	486
4– 6	21	14– 3	65	18–11	83	28–10	100	30–12	120	35–6	142	14– 9	60
12– 1	52	14– 4	65	50– 3	224	57–13	234	......	......	140–1	587	24– 2	172
7.60	**31.60**	**32.05**	**131.50**	**75.58**	**298.25**	**58.53**	**229.25**	**94.44**	**419.50**	**62.99**	**256.20**	**37.39**	**171.80**

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
93. Open strain—Contd.												
Variable fruits—												
1913–14	......	290	......	16	.....	0	.....	0	......	0	.....	......
1914–15	......	302	......	13	.....	12	.....	3	......	0	.....	1
1915–16	......	467	......	55	.....	59	.....	3	......	0	.....	0
1916–17	......	356	......	41	.....	3	.....	10	......	8	.....	7
Average	......	353.75	......	31.25	.....	18.50	.....	4.00	......	2.00	.....	2.67
Average seeds per fruit—												
1913–14	......	3.33	......	2	.....	3	.....	1	......	3	.....	......
1914–15	......	5.87	......	7	.....	3	.....	3	......	3	.....	3
1915–16	......	5.97	......	8	.....	9	.....	6	......	5	.....	7
Average	......	5.09	......	5.67	.....	4.89	.....	3.44	......	3.43	.....	4.60
101. Open strain:												
Green grade—												
1913–14	228–12	862	10– 6	40	4–14	21	0– 8	2	3– 2	14	.....	......
1914–15	148– 5	569	6– 4	26	6– 0	25	4–13	20	3– 4	13	8–14	34
1915–16	152–11	568	26–11	103	7– 8	30	1– 8	6	0– 0	0	0–13	3
1916–17	162– 2	624	18– 0	77	0–11	3	1– 1	4	0– 0	0	1–14	7
Average	172.97	655.75	15.33	61.50	4.77	19.75	1.97	8.00	1.59	6.75	3.85	14.67
Tree-Ripe grade—												
1913–14	101–10	436	5– 5	24	0– 2	1	0–12	6	2–14	21	.....	......
1914–15	328– 5	1,503	4–15	25	3– 5	20	15– 7	92	3– 6	19	0– 5	2
1915–16	143– 2	713	21– 9	96	2– 6	12	19– 3	97	12–12	91	3–13	25
1916–17	86– 6	415	21– 4	114	0– 7	3	0– 0	0	5–10	25	2– 0	9
Average	164.86	766.75	13,27	64.75	1.56	9.00	8.84	48.75	6.16	39.00	2.04	12.00
Cull grade—												
1913–14	12– 4	77	1– 0	7	0– 8	3	0– 2	1	1– 9	12	.....	......
1914–15	59–10	382	2– 3	14	4– 6	30	4–12	36	1– 4	9	1– 7	8
1915–16	94–15	608	19–10	128	12–11	76	23–15	156	1–11	14	2–13	22
1916–17	76– 0	499	3– 1	17	0–11	5	0– 0	0	0– 9	4	1– 7	12
Average	60.70	391.50	6.47	41.50	4.56	28.50	7.20	48.25	1.27	9.75	1.90	14.00
Total crop—												
1913–14	342–10	1,375	16–11	71	5– 8	25	1– 6	9	7– 9	47	.....	......
1914–15	536– 4	2,454	13– 6	65	13–11	75	25– 0	148	7–14	41	10–10	44
1915–16	390–12	1,889	67–14	327	22– 9	118	44–10	259	14– 7	105	7– 7	50
1916–17	324– 8	1,538	42– 5	208	1–13	11	1– 1	4	6– 3	29	5– 5	28
Average	**398.53**	**1,814.00**	**35.07**	**167.75**	**10.89**	**57.25**	**18.02**	**105.00**	**9.02**	**55.50**	**7.79**	**40.67**
Variable fruits—												
1913–14	......	131	......	1	.....	0	.....	0	......	0	.....	......
1914–15	......	84	......	5	.....	2	.....	0	......	0	.....	0
1915–16	......	292	......	7	.....	8	.....	2	......	0	.....	0
1916–17	......	192	......	61	.....	0	.....	0	......	1	.....	0
Average	......	174.75	......	18.50	.....	2.50	.....	0.50	......	0.25	.....	0
Average seeds per fruit—												
1913–14	......	5.41	......	3	.....	4	.....	4	......	3	.....	......
1914–15	......	6.79	......	4	.....	4	.....	7	......	6	.....	5
1915–16	......	8.09	......	7	.....	10	.....	10	......	5	.....	7
Average	......	6.82	......	4.78	.....	5.89	.....	6.89	......	4.75	.....	6.00
113. Open strain:												
Green grade—												
1913–14	190– 5	746	16–14	63	4– 7	19	0– 0	0	3– 4	14	.....	......
1914–15	155–10	589	8–15	39	2–12	11	6– 3	27	3– 8	14	3– 5	13
1915–16	109– 1	405	9–14	38	25– 6	100	2– 0	8	1– 5	5	1– 4	5
1916–17	162–14	634	22–12	102	1– 0	4	2– 8	9	1–13	7	1–12	7
Average	154.47	593.50	14.61	60.50	8.39	33.50	2.67	11.00	2.47	10.00	2.10	8.33

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
......	3	......	25	......	84	......	68	......	......	......	76	......	18
......	8	......	18	......	17	......	35	......	84	......	......	......	111
......	5	......	27	......	42	......	86	......	72	......	80	......	38
......	15	......	17	......	57	......	112	......	......	......	82	......	4
......	6.20	......	21.75	......	50.00	......	75.25	......	78.00	......	47.60	......	34.20
......	3	......	5	......	3	......	4	......	......	......	6	......	4
......	10	......	9	......	8	......	4	......	8	......	......	......	9
......	4	......	6	......	6	......	5	......	7	......	3	......	4
......	5.25	......	6.56	......	5.33	......	4.38	......	7.33	......	4.50	......	5.67
6- 0	22	45- 6	176	84- 8	307	44- 0	169	......	......	22- 7	81	7- 9	30
9- 4	36	14- 9	58	9-14	37	27- 9	105	28-0	104	......	......	29-14	111
0- 0	0	4- 6	16	10-10	41	10- 1	36	36-14	128	28- 9	107	25-11	98
9-13	40	3- 3	13	20-12	80	41-15	155	......	......	63-13	240	1- 0	5
5.01	19.60	16.88	65.75	31.44	116.25	30.89	116.25	32.44	116.00	22.96	85.60	12.83	48.80
0- 0	0	1-13	8	43- 3	166	23- 3	99	......	......	21- 6	98	3- 0	13
9-14	39	40- 6	172	22- 2	90	31- 8	128	159- 9	744	......	......	37- 8	172
4- 8	20	10-14	65	1- 4	7	0- 0	0	3- 2	13	48-12	215	14-15	72
3- 2	15	0- 4	1	6-12	27	6- 8	25	......	......	40- 7	196	0- 0	0
3.50	14.80	13.33	61.50	18.33	72.50	15.30	63.00	81.34	378.50	22.11	101.80	11.09	51.40
0- 4	2	0- 5	2	1-10	10	4- 6	25	......	......	1- 4	8	1- 4	7
0-14	5	2- 0	13	2- 4	13	5- 0	31	28-13	177	......	......	6-11	46
0-10	6	1-15	15	3-15	30	3-12	25	4- 5	24	11-14	67	7-12	45
0- 7	3	3- 2	26	7-12	53	9- 6	55	......	......	34- 0	205	15- 9	119
0.44	3.20	1.84	14.00	3.89	26.50	5.63	34.00	16.56	100.50	9.43	56.00	6.25	43.40
6- 4	24	47- 8	186	129- 5	483	71- 9	293	......	......	45- 1	187	11-13	50
20- 0	80	56-15	243	34- 4	140	64- 1	264	216- 6	1,025	......	......	74- 1	329
5- 2	26	17- 3	96	15-13	78	13-13	61	44- 5	165	89- 3	389	48- 6	215
13- 6	58	6- 9	40	35- 4	160	57-13	235	......	......	138- 4	641	16- 9	124
8.95	**37.60**	**32.05**	**141.25**	**53.66**	**215.25**	**51.81**	**213.25**	**130.34**	**595.00**	**54.50**	**243.40**	**30.16**	**143.60**
......	1	......	4	......	74	......	34	......	......	......	14	......	3
......	0	......	11	......	6	......	9	......	37	......	......	......	14
......	0	......	9	......	30	......	26	......	45	......	91	......	74
......	10	......	3	......	23	......	49	......	......	......	45	......	0
......	2.20	......	6.75	......	33.25	......	29.50	......	41.00	......	30.00	......	18.20
......	5	......	9	......	5	......	7	......	......	......	7	......	8
......	11	......	9	......	8	......	6	......	8	......	......	......	7
......	9	......	8	......	7	......	11	......	7	......	4	......	11
......	8.71	......	8.56	......	6.56	......	7.50	......	7.83	......	5.67	......	8.67
3- 6	15	43- 1	168	59-11	232	26- 4	106	......	......	24-15	96	8- 7	33
4- 4	16	19- 7	76	8-12	33	18-10	69	34-14	127	......	......	45- 0	164
0- 4	1	0- 9	2	3-13	15	12-13	46	20-14	71	14- 4	51	16-11	63
3- 8	14	4- 3	16	16-12	64	41- 4	152	......	......	66- 4	255	1- 2	4
2.28	9.20	16.81	65.50	22.25	86.00	24.73	93.25	27.88	99.00	21.09	80.40	14.25	52.80

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
113. Open strain—Contd.												
Tree-Ripe grade—												
1913–14	88–12	395	5– 8	25	0–13	5	0–14	6	5– 9	35	......	......
1914–15	218– 1	964	4– 1	21	2– 0	11	5– 5	28	2– 7	13	0– 6	2
1915–16	130– 3	656	11– 1	49	57– 6	274	14– 1	82	8– 8	55	3– 0	18
1916–17	90– 8	440	17– 6	105	0–15	5	0– 7	3	6– 5	29	0–12	3
Average	131.87	613.75	9.50	50.00	15.28	73.75	5.17	29.75	5.70	33.00	1.38	7.67
Cull grade—												
1913–14	13– 6	103	0–14	7	0–14	7	1– 2	11	3– 1	32	......	......
1914–15	60– 9	378	7– 6	44	3– 0	19	1–11	10	1– 3	9	0– 8	3
1915–16	64–13	404	13–14	79	17– 8	99	9– 2	65	1– 8	12	2– 8	20
1916–17	63– 0	410	7– 5	46	0– 9	4	0–10	4	0– 5	2	0– 8	5
Average	50.44	323.75	7.36	44.00	5.48	32.25	3.14	22.50	1.52	13.75	1.17	9.33
Total crop—												
1913–14	292– 7	1,244	23– 4	95	6– 2	31	2– 0	17	11–14	81	......	......
1914–15	434– 4	1,931	20– 6	104	7–12	41	13– 3	65	7– 2	36	4– 3	18
1915–16	304– 1	1,465	34–13	166	100–4	473	25– 3	155	11– 5	72	6–12	43
1916–17	316– 6	1,484	47– 7	253	2– 8	13	3– 9	16	8– 7	38	3– 0	15
Average	336.78	1,531.00	31.48	154.50	29.16	139.50	10.98	63.25	9.69	56.75	4.65	25.33
Variable fruits—												
1913–14	......	112	......	3	......	0	......	0	......	0	......	......
1914–15	......	120	......	6	......	4	......	6	......	0	......	0
1915–16	......	256	......	15	......	40	......	6	......	2	......	0
1916–17	......	203	......	79	......	3	......	4	......	0	......	3
Average	......	172.75	......	25.75	......	11.75	......	4.00	......	0.50	......	1.00
Average seeds per fruit—												
1913–14	......	5.59	......	7	......	4	......	4	......	4	......	......
1914–15	......	7.50	......	6	......	3	......	5	......	2	......	8
1915–16	......	6.82	......	8	......	8	......	6	......	5	......	6
Average	......	6.67	......	7.00	......	5.11	......	5.13	......	3.78	......	7.17
114. Dense-Unproductive strain:												
Green grade—												
1913–14	158– 1	579	7– 7	28	0–12	3	0– 9	2	1–15	7	......	......
1914–15	301– 0	1,060	1–12	6	0– 0	0	3–15	16	80–13	287	47– 6	161
1915–16	327– 5	1,190	8– 7	28	1– 1	4	1– 5	5	9–14	35	31–12	112
1916–17	251–10	932	10–14	45	1– 5	5	1–14	7	4– 5	15	20– 8	75
Average	259.75	940.25	7.13	26.75	0.78	3.00	1.92	7.50	24.23	86.00	33.21	116.00
Tree-Ripe grade—												
1913–14	3– 6	14	0–10	3	0– 4	1	0– 0	0	0–12	3	......	......
1914–15	7– 4	29	0–12	3	0– 0	0	0– 0	0	0– 0	0	0– 0	0
1915–16	0– 5	38	0–14	4	0– 0	0	2– 0	10	0– 9	2	0– 0	0
1916–17	24– 9	101	0–14	6	0– 3	1	0– 0	0	2–15	13	0– 5	2
Average	10.87	45.50	0.78	4.00	0.11	0.50	0.50	2.50	1.06	4.50	0.10	0.67
Cull grade—												
1913–14	2– 6	15	0– 8	4	0– 2	1	0– 0	0	0– 0	0	......	......
1914–15	4– 2	23	0– 4	1	0– 0	0	0– 0	0	0– 9	2	0– 9	2
1915–16	12– 4	67	0– 2	1	1– 3	6	1– 6	9	0– 0	0	0– 2	1
1916–17	26– 0	153	0– 0	0	0– 0	0	1– 6	14	0– 2	1	0–11	5
Average	11.19	64.50	0.22	1.50	0.32	1.75	0.69	5.75	0.17	0.75	0.46	2.67
Total crop—												
1913–14	163–13	608	8– 9	35	1– 2	5	0– 9	2	2–11	10	......	......
1914–15	312– 6	1,112	2–12	10	0– 0	0	3–15	16	81– 6	289	47–15	163
1915–16	347–14	1,295	9– 7	33	2– 4	10	4–11	24	10– 7	37	31–14	113
1916–17	303– 3	1,186	11–12	51	1– 8	6	3– 4	21	7– 6	29	21– 8	82
Average	281.81	1,050.25	8.13	32.25	1.22	5.25	3.11	15.75	25.47	91.25	33.77	119.33

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
0- 4	1	1-13	8	29- 2	118	14-10	63	......	......	24- 9	111	5-10	23
1- 4	5	18- 6	76	15- 1	60	19-10	81	102- 9	456	......	......	47- 0	211
5- 6	26	9- 5	54	0- 0	0	0- 0	0	3-14	16	10-11	48	6-15	34
2-10	13	1-15	9	3- 7	14	17- 0	70	......	......	37- 7	175	2- 4	14
1.90	9.00	7.86	36.75	11.91	48.00	12.81	53.50	53.22	236.00	14.54	66.80	12.36	56.40
0- 2	2	0- 7	2	1- 7	8	3- 7	20	......	......	1- 6	10	0-10	4
0- 0	0	1- 4	9	2- 8	15	7- 2	42	24-13	156	......	......	11- 2	71
3- 8	30	2- 1	13	1- 9	11	1- 1	7	3-12	22	2-14	17	5- 8	29
0- 8	4	1-11	13	7- 8	51	6- 6	49	......	......	28-14	161	8-12	71
0.83	7.20	1.36	9.25	3.25	21.25	4.50	29.50	14.28	89.00	6.63	37.60	5.20	35.00
3-12	18	45- 5	178	90- 4	358	44- 5	189	......	......	50-14	217	14-11	60
5- 8	21	39- 1	161	26- 5	108	45- 6	192	162- 4	739	......	......	103- 2	446
9- 2	57	11-15	69	5- 6	26	13-14	53	28- 8	109	27-13	116	29- 2	126
6-10	31	7-13	38	27-11	129	64-10	271	......	......	132- 9	591	12- 2	89
5.00	**25.40**	**26.03**	**111.50**	**37.41**	**155.25**	**42.05**	**176.25**	**95.38**	**424.00**	**42.25**	**184.80**	**31.81**	**144.20**
......	0	......	17	......	44	......	27	......	......	......	16	......	5
......	1	......	10	......	8	......	17	......	38	......	......	......	30
......	0	......	0	......	11	......	34	......	41	......	46	......	61
......	6	......	7	......	17	......	47	......	......	......	37	......	0
......	1.40	......	8.50	......	20.00	......	31.25	......	39.50	......	19.80	......	19.20
......	7	......	5	......	3	......	9	......	......	......	4	......	7
......	10	......	9	......	11	......	12	......	10	......	......	......	7
......	6	......	8	......	7	......	9	......	9	......	6	......	5
......	7.50	......	7.22	......	7.13	......	10.13	......	9.33	......	5.50	......	6.11
31-11	112	48- 2	182	50-14	184	11- 8	42	......	......	4-10	17	0- 9	2
41-12	147	44-13	166	26- 0	91	20-12	74	......	......	26- 2	86	7-11	26
59- 1	211	71-13	270	60- 5	234	18- 7	65	39-12	137	17- 9	62	7-15	27
37- 6	138	19- 5	74	57-10	210	30-11	110	......	......	68- 0	250	0-12	3
33.98	121.60	46.01	173.00	48.70	179.75	20.34	72.75	39.75	137.00	16.62	59.29	4.23	14.50
0- 3	1	0- 0	0	0- 0	0	0- 5	1	......	......	1- 0	4	0- 4	1
0- 0	0	0- 8	2	1- 0	4	1- 8	6	......	......	1-12	7	1-12	7
0- 0	0	0- 3	1	0- 0	0	0- 5	2	0- 8	2	1-11	7	2- 3	10
0- 0	0	1- 9	7	1-12	6	7- 7	28	......	......	9- 8	38	0- 0	0
0.04	0.20	0.56	2.50	0.69	2.50	2.39	9.25	0.50	2.00	1.99	8.00	1.05	4.50
0- 4	2	0- 5	1	1- 0	6	0- 0	0	......	......	0- 3	1	0- 0	0
0-11	4	0- 8	3	0- 3	1	0- 0	0	......	......	0-10	5	0-12	5
0-10	6	1- 0	6	5-11	27	0- 3	1	0-10	3	0- 9	3	0-12	4
0- 6	3	0- 4	2	3- 9	22	0- 8	4	......	......	9- 6	46	9-12	56
0.39	3.00	0.52	3.00	2.61	14.00	0.17	1.25	0.63	3.00	1.54	7.86	2.81	16.25
32- 2	115	48- 7	183	51-14	190	11-13	43	......	......	5-13	22	0-13	3
42- 7	151	45-13	171	27- 3	96	22- 4	80	......	......	28- 8	98	10- 3	38
59-11	217	73- 0	277	66- 0	261	18-15	68	40-14	142	19-13	72	10-14	41
37-12	141	21- 2	83	62-15	238	38-10	142	......	......	86-14	334	10- 8	59
34.40	**124.80**	**47.09**	**178.50**	**52.00**	**196.25**	**22.91**	**83.25**	**40.88**	**142.00**	**20.14**	**75.14**	**8.09**	**35.25**

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
114. Dense-Unproductive strain—Continued.												
Variable fruits—												
1913–14	......	510	......	25	.....	4	.....	2	......	7	.....	......
1914–15	......	707	......	0	.....	......	.....	1	......	61	.....	83
1915–16	......	876	......	15	.....	4	.....	2	......	18	.....	42
1916–17	......	863	......	36	.....	4	.....	3	......	13	.....	45
Average	......	739.00	......	19.00	.....	3.00	.....	2.00	......	24.75	.....	56.67
Average seeds per fruit—												
1913–14	......	2.61	......	4	.....	4	.....	3	......	4	.....	......
1914–15	......	.33	......	0	.....	......	.....	0	......	0	.....	0
1915–16	......	1.29	......	1	.....	1	.....	1	......	0	.....	2
Average	......	1.38	......	1.78	.....	2.80	.....	1.80	......	1.50	.....	0.75
117. Dense-Unproductive strain:												
Green grade—												
1913–14	183– 5	697	10– 9	42	0–11	3	0– 0	0	0– 0	0	.....	......
1914–15	168–14	607	2– 6	10	0– 0	0	1– 2	5	41– 0	150	18– 0	66
1915–16	267– 7	977	2– 3	8	0– 0	0	2– 7	8	12–13	46	21– 2	77
1916–17	167– 8	626	8–13	41	0– 0	0	0– 9	2	5–12	22	11– 9	43
Average	196.78	726.75	5.98	25.25	0.17	0.75	1.03	3.75	14.89	54.50	16.90	62.00
Tree-Ripe grade—												
1913–14	4– 1	19	1– 8	7	0– 6	2	0– 6	2	0– 4	1	.....	......
1914–15	7– 3	31	4– 0	17	0– 0	0	0– 3	1	0– 0	0	0– 0	0
1915–16	3–15	17	0– 7	2	0– 0	0	0– 7	2	0–13	3	0– 3	1
1916–17	16– 1	69	2– 1	13	0– 0	0	0– 0	0	0– 0	0	0– 8	2
Average	7.81	34.00	2.00	9.75	0.09	0.50	0.25	1.25	0.27	1.00	0.23	1.00
Cull grade—												
1913–14	2–13	16	0– 7	4	0– 0	0	0– 0	0	0– 1	1	.....	......
1914–15	1–10	8	0–11	3	0– 0	0	0– 0	0	0– 0	0	0– 0	0
1915–16	14– 0	70	0– 5	2	0– 0	0	0– 6	3	0– 0	0	1– 2	7
1916–17	33– 8	199	1– 8	7	0– 0	0	1– 5	15	0– 0	0	0– 2	1
Average	12.98	73.25	0.73	4.00	0	0	0.42	4.50	0.02	0.25	0.42	2.68
Total crop—												
1913–14	190– 3	732	12– 8	53	1– 1	5	0– 6	2	0– 5	2	.....	......
1914–15	177–11	646	7– 1	30	0– 0	0	1– 5	6	41– 0	150	18– 0	66
1915–16	285– 6	1,064	2–15	12	0– 0	0	3– 4	13	13–10	49	22– 7	85
1916–17	217– 1	894	12– 6	61	0– 0	0	1–14	17	5–12	22	12– 3	46
Average	217.58	834.00	8.72	39.00	0.27	1.25	1.70	9.50	15.17	55.75	17.54	65.67
Variable fruits—												
1913–14	......	648	......	31	.....	5	.....	2	......	1	.....	......
1914–15	......	512	......	30	.....	0	.....	6	......	46	.....	64
1915–16	......	725	......	6	.....	0	.....	4	......	20	.....	35
1916–17	......	564	......	36	.....	0	.....	1	......	14	.....	28
Average	......	612.25	......	25.75	.....	1.25	.....	3.25	......	20.25	.....	42.33
Average seeds per fruit—												
1913–14	......	1.40	......	3	.....	2	.....	5	......	4	.....	......
1914–15	......	1.83	......	1	.....	0	.....	1	......	2	.....	0
1915–16	......	1.04	......	2	.....	0	.....	5	......	1	.....	1
Average	......	1.55	......	1.78	.....	2.00	.....	3.50	......	2.00	.....	0.25
121. Dense-Unproductive strain:												
Green grade—												
1913–14	124– 2	465	13– 6	50	1– 0	4	0– 4	1	1– 1	4	.....	......
1914–15	155– 8	562	0–12	3	0– 0	0	2–13	11	42– 3	155	25– 0	89
1915–16	190– 4	707	1–10	6	0– 0	0	1– 1	4	7– 0	26	19– 8	71
1916–17	78–10	316	4–11	19	0– 0	0	0–13	3	1– 9	6	4– 6	17
Average	137.13	512.50	5.11	19.50	0.25	1.00	1.23	4.75	12.95	47.75	16.29	59.00

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
....	101	....	163	....	150	....	37	....	....	....	18	....	3
....	108	....	153	....	96	....	80	....	....	....	95	....	30
....	119	....	235	....	193	....	49	....	124	....	49	....	26
....	110	....	60	....	190	....	125	....	....	....	237	....	40
....	87.60	....	152.75	....	157.25	....	72.75	....	124.00	....	57.00	....	24.75
....	4	....	0	....	1	....	2	....	....	....	1	....	0
....	0	....	0	....	1	....	1	....	....	....	1	....	0
....	3	....	2	....	1	....	1	....	1	....	2	....	2
....	2.29	....	0.88	....	0.57	....	1.14	....	0.67	....	1.56	....	0.75
8–13	34	39– 2	153	79–10	295	29– 8	112	....	....	12–14	50	2– 2	8
20–11	74	30– 5	113	30– 1	102	10–12	39	....	....	7–12	26	6–13	22
56–14	202	70– 3	271	29– 8	115	16– 4	56	33–12	117	11–15	41	10– 6	36
19–11	74	9– 4	36	35– 8	129	22– 8	81	....	....	53– 2	195	0–12	3
21.21	76.80	37.22	143.25	43.67	160.25	19.75	72.00	33.75	117.00	12.24	44.57	5.02	17.25
0– 4	1	0– 0	0	0– 0	0	0– 4	1	....	....	0– 9	3	0– 8	2
0– 4	1	0– 4	1	0– 3	1	0–10	3	....	....	0–15	4	0–12	3
0– 0	0	0– 0	0	0– 0	0	0– 0	0	1– 1	4	1– 0	5	0– 0	0
0– 0	0	0– 6	2	0–13	3	3–10	14	....	....	8–11	35	0– 0	0
0.10	0.40	0.16	0.75	0.25	1.00	1.13	4.50	1.06	4.00	1.60	6.71	0.31	1.25
0– 2	1	0– 0	0	1– 8	7	0– 3	1	....	....	0– 4	1	0– 4	1
0– 3	1	0– 3	1	0– 8	2	0– 0	0	....	....	0– 0	0	0– 1	1
0–14	4	0– 3	1	7–14	38	0– 0	0	0–14	4	2– 2	9	0– 4	2
0– 4	2	0– 4	2	12– 2	71	0– 5	2	....	....	10–12	55	6– 1	4 44
0.29	1.60	0.16	1.00	5.50	29.50	0.13	0.75	0.88	4.00	1.88	9.29	1.86	12.00
9– 3	36	39– 2	153	81– 2	302	29–15	114	....	....	13–11	54	2–14	11
21– 2	76	30–12	115	30–12	105	11– 6	42	....	....	8–11	30	7–10	26
57–12	206	70– 6	272	37– 6	153	16– 4	56	35–11	125	15– 1	55	10–10	38
19–15	76	9–14	40	48– 7	203	26– 7	97	....	....	72– 9	285	7–10	47
21.60	**78.80**	**37.53**	**145.00**	**49.42**	**190.75**	**21.00**	**77.25**	**35.69**	**125.00**	**15.71**	**60.57**	**7.19**	**30.50**
....	28	....	137	....	281	....	111	....	....	....	43	....	9
....	52	....	113	....	105	....	42	....	....	....	29	....	25
....	132	....	219	....	100	....	50	....	103	....	31	....	25
....	60	....	28	....	123	....	89	....	....	....	151	....	34
....	54.40	....	124.25	....	152.25	....	73.00	....	103.00	....	36.28	....	23.25
....	2	....	0	....	0	....	0	....	....	....	3	....	1
....	3	....	0	....	0	....	4	....	....	....	5	....	3
....	1	....	0	....	0	....	0	....	0	....	0	....	1
....	2.29	....	0	....	0	....	1.50	....	0	....	2.50	....	1.50
13–10	52	27– 1	105	46– 5	168	16–12	63	....	....	3–15	15	0–12	3
23– 7	84	20– 6	77	16–11	59	8–13	31	....	....	11– 6	39	4– 1	14
43– 6	157	40– 1	156	26– 2	100	14– 0	52	22–13	82	10– 9	38	4– 2	15
10–13	41	4–11	18	16–13	64	4–14	18	....	....	30– 0	130	0– 0	0
18.25	66.80	23.05	89.00	26.48	97.75	11.11	41.00	22.81	82.00	7.98	31.71	2.23	8.00

TABLE III.—*Detailed statement of the annual performance of 25 representative lemon*

Rank in Table I, strain, grade, and season.	Total.		July.		August.		September.		October.		November.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
121. Dense-Unproductive strain—Continued.												
Tree-Ripe grade—												
1913–14	8– 0	39	3– 0	16	0– 5	2	0– 4	1	0–11	3	......	......
1914–15	6–12	27	0–14	4	0– 0	0	0– 0	0	0– 0	0	0– 0	0
1915–16	11– 8	52	0– 4	1	0– 0	0	0–11	4	0–14	4	0– 8	3
1916–17	16–12	80	0– 9	3	0– 0	0	0– 0	0	0– 3	1	0– 4	1
Average	10.75	49.50	1.17	6.00	0.08	0.50	0.23	1.25	0.44	2.00	0.25	1.33
Cull grade—												
1913–14	3– 1	19	0– 6	3	0– 0	0	0– 0	0	0– 6	2	......	......
1914–15	2–14	16	0–12	4	0– 0	0	0– 3	1	0– 9	2	0– 0	0
1915–16	21– 1	106	0– 8	2	0– 3	1	1– 1	6	0– 3	1	0– 4	2
1916–17	20– 8	126	0– 5	2	0– 8	4	0– 0	0	0– 5	2	0– 0	0
Average	11.88	66.75	0.48	2.75	0.17	1.25	0.31	1.75	0.36	1.75	0.08	0.67
Total crop—												
1913–14	135– 3	523	16–12	69	1– 5	6	0– 8	2	2– 2	9	......	......
1914–15	165– 2	605	2– 6	11	0– 0	0	3– 0	12	42–12	157	25– 0	89
1915–16	222–13	865	2– 6	9	0– 3	1	2–13	14	8– 1	31	20– 4	76
1916–17	115–14	522	5– 9	24	0– 8	4	0–13	3	2– 1	9	4–10	18
Average	159.75	628.75	6.77	28.25	0.50	2.75	1.78	7.75	13.75	51.50	16.63	61.00
Variable fruits—												
1913–14	......	411	......	59	.....	5	.....	2	......	7	.....	......
1914–15	......	474	......	11	.....	0	.....	12	......	40	.....	89
1915–16	......	556	......	3	.....	0	.....	2	......	16	.....	36
1916–17	......	293	......	21	.....	0	.....	2	......	2	.....	12
Average	......	433.50	......	23.50	.....	1.25	.....	4.50	......	16.25	.....	45.67
Average seeds per fruit—												
1913–14	......	3.48	......	3	.....	3	.....	5	......	2	.....	......
1914–15	......	2.36	......	2	.....	0	.....	3	......	0	.....	0
1915–16	......	1.35	......	1	.....	1	.....	2	......	4	.....	0
Average	......	2.29	......	2.11	.....	2.33	.....	3.29	......	2.13	.....	0

trees of the Lisbon variety for the 6-year period from July, 1913, to June, 1917—Contd.

December.		January.		February.		March.		April.		May.		June.	
Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
0– 3	2	0– 0	0	0– 0	0	1– 0	4	....	....	1– 8	7	1– 1	4
0– 0	0	0– 0	0	0–12	3	1– 8	6	....	....	1– 4	5	2– 6	9
0– 4	1	0– 0	0	0– 0	0	0– 0	0	1–11	7	5– 3	23	2– 1	9
0– 3	1	1–11	9	0– 9	2	3– 5	13	....	....	10– 0	50	0– 0	0
0.13	0.80	0.42	2.25	0.33	1.25	1.45	5.75	1.69	7.00	2.56	12.14	1.38	5.50
0– 8	3	0– 4	2	0– 9	3	0– 4	2	....	....	0–12	4	0– 0	0
0– 0	0	0– 4	2	0– 2	1	0– 0	0	....	....	0–10	4	0– 6	2
0– 4	1	1–13	10	11– 3	55	0– 5	2	2– 2	11	2–11	12	0– 8	3
0– 4	2	0– 4	2	4– 8	28	0– 0	0	....	....	10– 0	54	4– 6	32
0.20	1.20	0.64	4.00	4.09	21.75	0.14	1.00	2.12	11.00	2.01	10.57	1.31	9.25
14– 5	57	27– 5	107	46–14	171	18– 0	69	....	....	6– 3	26	1–13	7
23– 7	84	20–10	79	17– 9	63	10– 5	37	....	....	13– 4	48	6–13	25
43–14	159	41–14	166	37– 5	155	14– 5	54	26–10	100	18– 7	73	6–11	27
11– 4	44	6–10	29	21–14	94	8– 3	31	....	....	50– 0	234	4– 6	32
18.58	**68.80**	**24.11**	**95.25**	**30.91**	**120.75**	**12.70**	**47.75**	**26.63**	**100.00**	**12.55**	**54.43**	**4.92**	**22.75**
....	44	....	84	....	133	....	54	....	....	....	18	....	5
....	78	....	77	....	63	....	37	....	....	....	44	....	23
....	107	....	126	....	83	....	36	....	79	....	49	....	19
....	35	....	14	....	61	....	22	....	....	....	104	....	20
....	52.80	....	75.25	....	85.00	....	37.25	....	79.00	....	30.71	....	16.75
....	4	....	4	....	3	....	4	....	....	....	5	....	3
....	1	....	2	....	4	....	3	....	....	....	2	....	3
....	0	....	1	....	2	....	0	....	1	....	1	....	3
....	2.00	....	1.80	....	3.33	....	2.29	....	0.33	....	2.56	....	3.13

TABLE IV.—*Number of variable fruits of different forms produced during the investigational performance-record period on the 25 individual lemon trees of the Lisbon variety listed in Table III.*

[These data are for the 4-year period from July, 1913, to June, 1917, inclusive, except that the records for the trees of the Bull strain are for the 3-year period from July, 1914, to June, 1917, inclusive. The several trees are designated by numbers denoting their rank (as shown in Table III), the strain to which each belongs being indicated by abbreviations, as follows: B=Bull, DU=Dense-Unproductive, L=Lisbon, O=Open, S=Sporting.]

Description of fruit variations.	Tree designations by rank and strain.												
	1, L.	5, B.	6, L.	10, B.	13, L.	17, L.	22, S.	24, B.	26, L.	29, O.	39, O.	50, O.	57, B.
Collared	1,976	1,828	1,746	1,850	1,633	1,927	1,252	1,415	1,513	931	1,007	897	1,324
Protruding blossom end	598	393	697	356	535	505	425	501	427	264	337	254	367
Collared and protruding	1,216	734	1,087	601	1,148	804	788	762	667	481	451	397	610
Bottle shape	109	3	54	6	93	33	95	......	21	44	61	62	7
Raised section	9	......	19	......	10	18	12	2	13	11	2	5	8
Raised ridge	49	29	57	37	48	39	54	43	40	32	14	20	32
Ridged	90	134	111	121	81	196	235	150	141	51	36	49	167
Ridged and collared	70	43	64	49	76	108	610	40	36	33	36	29	77
Ridged and protruding	41	26	63	36	38	80	56	29	45	8	5	15	24
Ridged, collared, and protruding	55	41	70	36	52	70	160	56	22	7	12	4	58
Sunken section	3	......	6	1	5	5	11	2	3	4	......	1	1
Creased	23	22	36	20	17	40	14	16	43	23	23	18	33
White section	1	......	......	......	......	3	......	1	1	......	......	......	......
Striped	......	1	5	......	1	9	2	......	7	......	......	......	35
Striped section	......	......	......	......	......	......	......	......	......	......	......	......	2
Ribbed	......	......	11	1	2	2	95	1	4	......	......	......	1
Corrugated	6	......	13	......	15	14	969	......	6	......	......	......	60
Abnormal shape	5	3	4	1	1	2	2	2	3	1	1	1	1
Miscellaneous variations	8	26	17	27	14	14	25	31	20	......	6	......	25
Total	4,259	3,283	4,060	3,142	3,769	3,869	4,805	3,051	3,012	1,890	1,991	1,752	2,832
Percentage of total crop	36.7	43.3	39.2	42.7	36.2	39.3	50.6	44.9	32.8	19.9	22.2	19.5	48.0

Description of fruit variations.	Tree designations by rank and strain.											
	59, O.	67, O.	75, O.	76, L.	81, S.	85, O.	93, O.	101, O.	113, O.	114, DU.	117, DU.	121, DU.
Collared	889	626	677	719	1,251	450	754	363	367	817	473	266
Protruding blossom end	249	247	253	279	498	826	120	151	154	12	8	5
Collared and protruding	471	306	316	382	740	514	318	105	85	2	6	29
Bottle shape	47	52	36	46	63	4	106	11	25	183	156	150
Raised section	5	5	5	3	10	5	5	......	1	3	31	1
Raised ridge	25	20	20	12	75	20	13	6	4	68	45	21
Ridged	39	42	30	36	168	68	44	22	25	378	370	281
Ridged and collared	30	23	17	30	151	18	21	7	2	1,403	1,318	942
Ridged and protruding	14	11	15	13	30	32	7	15	11	2	1	1
Ridged, collared, and protruding	7	8	6	11	68	5	5	2	2	2	6	6
Sunken section	1	2	1	......	3	1	......	1	......	2	4	3
Creased	30	18	11	15	12	21	20	10	7	23	8	9
White section	......	......	......	......	......	......	......	......	......	......	......	......
Striped	1	......	......	......	13	......	......	......	......	27	2	1
Striped section	......	1	......	......	1	......	......	......	......	......	......	......
Ribbed	......	......	......	......	9	......	......	......	......	9	9	12
Corrugated	......	......	......	......	152	......	......	......	......	3	2	......
Abnormal shape	3	......	2	2	1	4	......	2	5	6	2	2
Miscellaneous variations	2	4	5	2	23	9	2	4	3	16	8	5
Total	1,813	1,365	1,394	1,550	3,268	1,977	1,415	699	691	2,956	2,449	1,734
Percentage of total crop	21.6	16.1	17.2	20.2	47.7	25.6	18.8	9.6	11.3	70.4	73.4	68.9

The collared and ridged forms recorded for the trees of the Dense-Unproductive strain are characteristic of that strain. They vary somewhat from the fruits on the other trees listed under the same designations, but have been recorded under the same names. The fruits of the Bull strain are typically somewhat collared and inclined to be ridged, but only the fruits which showed those characteristics in a marked degree were recorded in those classes during these studies. The trees of the Open strain produce less fruit of these fluctuating forms than any of the other strains of the Lisbon variety which have been studied.

In Table V are recorded the dates on which each picking was made from the trees in the Lisbon study plat during the four years, July, 1913, to June, 1917, inclusive. An attempt was made to obtain the picking records at intervals of 30 days. Unavoidable delays, however, were sometimes occasioned by unfavorable conditions of climate, by interfering periods of irrigation, or by other causes. Unfavorable weather conditions during the winter season often delayed the progress of the work from a day to several weeks. At four times during the period from July, 1913, to June, 1917, it was impossible to make a picking at the proper time. In April, 1915, owing to certain conditions in the orchard, it was thought best to begin the picking from the side of the plat opposite to that which had been the previous practice. This made about a 30-day interval between the first trees picked at that time and an increasing interval up to nearly two months for the rest of the plat. The trees picked first were credited with an April yield, but with no picking in May. The trees picked during the latter part of that period were listed with a crop in May, but with no picking in April.

Table V.—*Dates on which fruit was picked from the lemon trees of the Lisbon variety in the investigational performance-record plat from July, 1913, to June, 1917, inclusive.*

[When this plat was selected the trees had not been picked for about five weeks, so the records were begun on them at once and credited as the July crop.]

Month.	First and last date of each picking period.			
	1913–14	1914–15	1915–16	1916–17
July	June 27 to July 2	July 15 to 20	July 3 to 17	July 20 to 25.
August	Aug. 13 to 16	Aug. 18 to 21	Aug. 10 to 13	Aug. 21 to 26.
September	Sept. 13 to 17	Sept. 22 to 25	Sept. 9 to 14	Sept. 26 and 27.
October	Oct. 27 to 29	Oct. 26 to 31	Oct. 12 to 14	Oct. 23 to 25.
November		Nov. 23 to 28	Nov. 11 and 12	Nov. 20 to 22.
December	Dec. 9 to 11	Dec. 23 to 30	Dec. 10 to 15	Dec. 20 to 24.
January	Jan. 3 to 19	Jan. 15 to Feb. 1	Jan. 7 to 20	Jan. 22 to 25.
February	Feb. 16 to Mar. 6	Feb. 24 to Mar. 3	Feb. 8 to 14	Feb. 23 to 28.
March	Mar. 24 to Apr. 2	Mar. 17 to 25	Mar. 8 to 13	Mar. 28 to Apr. 5.
April			Apr. 12 to 17	
May	May 5 to 13	Apr. 27 to May 10 [a]	May 10 to 13	May 15 to 18.
June	June 3 to 8	June 2 to 9	June 2 to 5 [b]	July 6 to 7.[c]

[a] Owing to delay caused by irrigation and cultivation the order of picking the trees was here reversed and the new order was followed in all subsequent work. The trees which were picked on March 25 at the end of the March picking were picked again on April 27, while those picked on March 17 were not picked again until May 10.

[b] The 15 trees on the western section of the plat were not picked until June 19 and 20.

[c] The 15 trees on the western section of the plat were not picked in April or May, but were picked on June 18 and 19.

Table VI presents the average annual yield of the lemon trees of the various strains of the Lisbon variety in the investigational plat, showing their total crops and the yields of Green, Tree-Ripe, and Cull fruits. Figure 4 shows these data graphically, and the percentage of fruit of each grade is shown in Table VII. The Lisbon strain is seen to be the most productive one. The Bull strain is very nearly as productive and bore a higher proportion of green fruit, but the lower quality and poor appearance of the fruit of that strain make it much less desirable than that of the Lisbon strain. The low average of the Dense-Unproductive strain and its high percentage of Green-grade fruit is particularly noticeable. Every tree of this strain produced more fruit of the Cull grade than of the Tree-Ripe grade. The fruit borne by the trees of this strain is of very little value commercially. The trees of all the strains except the Open strain are characterized by a dense or semidense habit of growth, and the effect of this condition is reflected in the percentage of fruit of the Cull grade produced by the trees of the different strains. Table VII shows the trees of the Open strain to have had 11.8 per cent of fruit of the Cull grade, the next highest proportion, 5.16 per cent, being borne by the trees of the Dense-Unproductive strain.

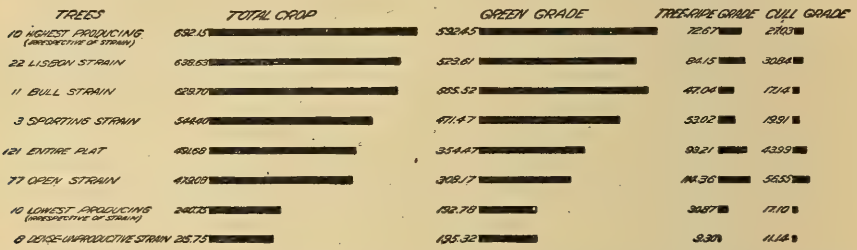

FIG. 4.—Diagram showing the average annual total crops and the weight of fruit of the different commercial grades produced by the trees of the several strains of the Lisbon lemon occurring in the investigational performance-record plat during the 4-year period from July, 1913, to June, 1917, inclusive. The data for the trees of the Bull strain and three other trees, as indicated in Table I, cover only three years. The strains are ranked according to the weight of their average total crops.

The last two columns of Table VII show the average number and percentage of variable fruits produced by the trees of the different strains during the performance-record period. While all except the Open strain are shown to bear very large percentages of fruit of variable forms, the greater proportion of them on the trees of the Bull, Lisbon, and Open strains are of the fluctuating type previously described. The fruits of the Dense-Unproductive strain are practically all of forms characteristic of that strain, and the trees of the Sporting strain produce a relatively large percentage of fruit which differs very markedly from the typical fruit of the variety. Figure 5 shows graphically the variations between the different strains in the percentage of variable fruit produced.

TABLE VI.—*Average annual crop of the individual lemon trees of several of the important strains occurring in the investigational performance-record plat of the Lisbon variety, ranked according to the weight of their average total crops.*

[This is a summary of data for the 4-year period from July, 1913, to June, 1917, inclusive, except that the data for the trees of the Bull strain and three other trees, as indicated in Table I, cover only the 3-year period from July, 1914, to June, 1917, inclusive.]

Number of trees.	Description of trees.	Average annual production per tree.							
		Total crop.		Green grade.		Tree-Ripe grade.		Cull grade.	
		Pounds.	Number.	Pounds.	Number.	Pounds.	Number.	Pounds.	Number.
10	Highest producing (irrespective of strain)	692.15	2,614.03	592.45	2,147.05	72.67	302.08	27.03	164.90
22	Lisbon strain	638.63	2,482.99	523.61	1,925.63	84.15	363.27	30.84	194.09
11	Bull strain	629.70	2,307.79	565.52	2,020.21	47.04	187.85	17.14	99.73
3	Sporting strain	544.40	2,032.75	471.47	1,703.50	53.02	209.33	19.91	119.92
121	Entire plat	491.68	1,994.11	354.47	1,304.37	93.21	412.48	43.99	277.26
77	Open strain	479.08	2,012.22	308.17	1,142.07	114.36	512.05	56.55	358.10
10	Lowest producing (irrespective of strain)	240.75	957.80	192.78	712.40	30.87	139.75	17.10	105.65
8	Dense - Unproductive strain	215.75	822.84	195.32	718.44	9.30	39.12	11.14	65.28

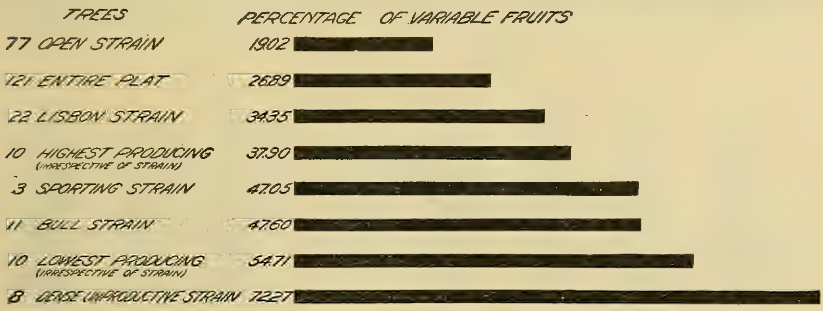

FIG. 5.—Diagram showing the percentage of variable fruits of the Lisbon lemon occurring on the trees of the different strains in the investigational performance-record plat during the 4-year period from July, 1913, to June, 1917, inclusive. The data for the trees of the Bull strain and three other trees, as indicated in Table I, cover only three years. The proportions are based on the number of fruits produced.

TABLE VII.—*Production of fruit of the three different grades and of variable fruits picked from the lemon trees of the several strains of the Lisbon variety in the investigational performance-record plat during the 4-year period from July, 1913, to June, 1917, inclusive.*

[The strains are ranked according to their proportion (by weight) of fruit of the Green grade.]

Number of trees.	Description of trees.	Percentage of weight of total crop.			Variable fruits.	
		Green grade.	Tree-Ripe grade.	Cull grade.	Average yearly number per tree.	Per cent.
8	Dense-Unproductive strain	90.53	4.31	5.16	594.56	72.27
11	Bull strain	89.81	7.47	2.72	1,098.67	47.60
3	Sporting strain	86.60	9.74	3.66	956.50	47.05
10	Highest producing (irrespective of strain)	85.59	10.50	3.91	990.60	37.90
22	Lisbon strain	81.99	13.18	4.83	853.02	34.35
10	Lowest producing (irrespective of strain)	80.07	12.82	7.10	524.00	54.71
121	Entire plat	72.09	18.96	8.95	536.26	26.89
77	Open strain	64.33	23.87	11.80	382.75	19.02

Table VIII and figures 6, 7, and 8 show some of the recorded variations in season of production of fruit of the Green and Tree-Ripe grades by the trees of the various strains in the Lisbon study plat. These figures include the records for the 3-year period from July, 1914, to June, 1917, inclusive, instead of for the entire four years, so as to make the data more closely comparable with the similar studies on the Eureka variety.[1] Pickings were made each month during these three years except in April, 1915, and again in April, 1917, as shown in Table V. No picking was made from the 14 trees in rows 56 and 57 in April or May, 1917. Although it was certain that at that season the amount picked from the trees was not equal each month, the only possible procedure was to credit the fruit equally to the months in question.

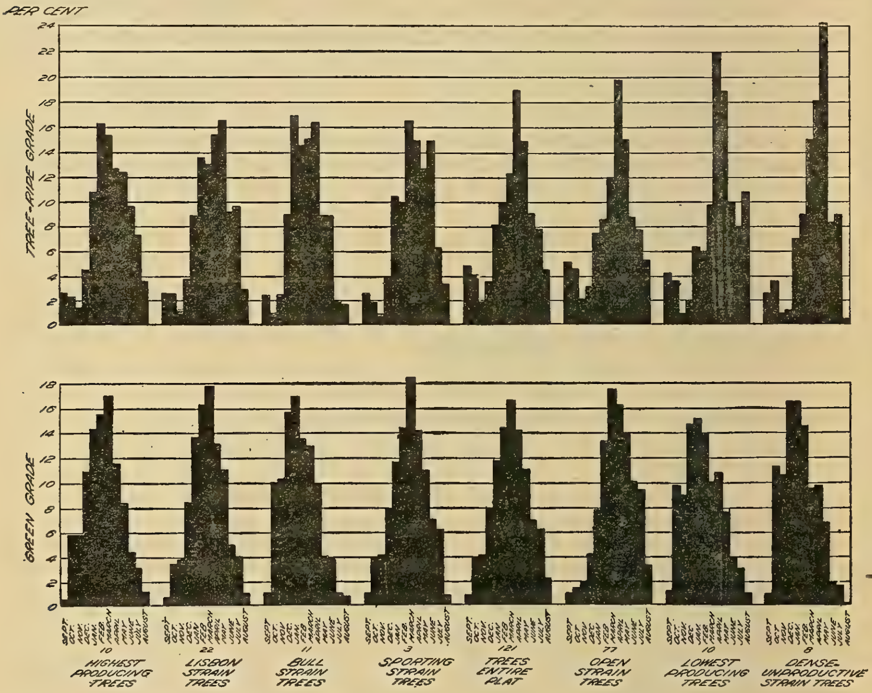

FIG. 6.—Diagram showing the percentage of the total yield of fruit of Lisbon lemons of the Green and Tree-Ripe grades, by weight, which was produced each month by the trees of the various strains in the investigational performance-record plat during the 3-year period from July, 1914, to June, 1917, inclusive. The strains are arranged from left to right in the order of their rank for total production, as shown in Table V.

The size of the picking ring used for fruit of the Green grade during the 4-year period is shown in Table IX. The fruit of the Tree-Ripe grade was usually "cleaned up" in April and May in this orchard.

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[1] See U. S. Dept. of Agriculture Bul. 813, entitled "Citrus Fruit Improvement: A Study of Bud Variation in the Eureka Lemon."

Table VIII shows the average monthly production of fruit of the Green and Tree-Ripe grades by the trees of the various strains and also presents these same data in terms of monthly percentages of the average annual production of each grade. In this latter form the data for the various strains are directly comparable, showing the variations between the strains in season of bearing. These variations are more clearly presented in figures 6 and 7. In figure 6 the monthly percentages of production are grouped by strains.

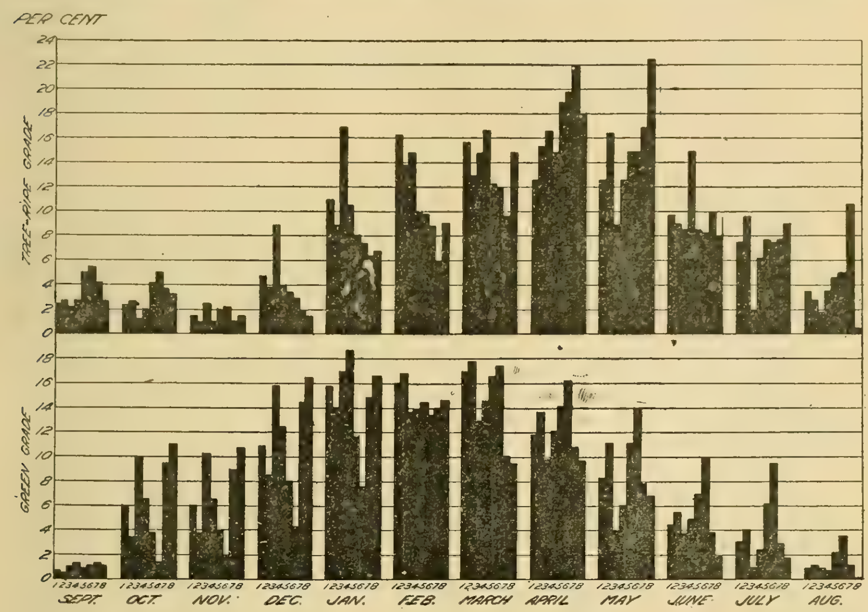

FIG. 7.—Diagram showing the percentage of the total yield of fruit of Lisbon lemons of the Green and Tree-Ripe grades, by weight, which was produced each month by the trees of the various strains in the investigational performance-record plat during the 3-year period from July, 1914, to June, 1917, inclusive. These are the same data that are presented in figure 6, being here rearranged to show more clearly the variations between the different strains each month. The strains are listed from left to right in the same order as in figure 6. Arrangement of strains: *1*, 10 highest producing trees; *2*, 22 trees of the Lisbon strain; *3*, 11 trees of the Bull strain; *4*, 3 trees of the Sporting strain; *5*, 121 trees—entire plat; *6*, 77 trees of the Open strain; *7*, 10 lowest producing trees; *8*, 8 trees of the Dense-Unproductive strain.

The trees of the Lisbon strain are shown to have borne most heavily of fruit of the Green grade in January, February, March, and April, being at their maximum in March, although Table V shows that the interval between the February and March pickings in 1915 was only 21 days and Table IX shows that the picking ring was increased in size in March, 1916. The trees of the Bull strain produced the largest crops of the Green grade in December, January, February, and March, being at their maximum in January, a condition partly due to the fact that, as shown in Table IX, the size of the picking ring was reduced in that month in two of the three years, although it was increased in size in that month in the third year. The trees of the Open strain bore most heavily of fruit of the Green grade in February, March, April, and May, being heaviest in March, like the trees of the Lisbon strain. The trees of the Dense-Unproductive strain bore the most of their fruit of the Green grade from October to February, inclusive, yielding their heaviest crops in December and January.

TABLE VIII.—*Average yield and percentages of total yield of fruit of the Green and Tree-Ripe grades picked each month from the lemon trees of the various strains of the Lisbon variety in the investigational performance-record plat during the 3-year period from July, 1914, to June, 1917, inclusive.*

[The strains are listed in the order of their total-production rank for 4 years, as shown in Table VI.]

Description of trees.	Number of trees.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Total.
PRODUCTION (IN POUNDS) AVERAGE.														
Green grade:														
Highest producing (irrespective of strain)	10	18.52	5.55	3.60	35.34	35.81	66.23	89.05	96.45	101.42	70.81	50.37	26.60	599.75
Lisbon strain	22	21.95	5.84	2.86	18.23	20.40	45.65	74.42	88.79	94.85	72.71	60.03	27.11	532.86
Bull strain	11	6.95	5.10	6.08	56.13	58.09	89.16	96.35	77.12	74.42	56.04	22.60	20.82	568.85
Sporting strain	3	11.92	3.94	6.53	33.63	32.17	61.76	90.83	68.14	71.63	60.25	30.41	23.50	494.72
Entire plat	121	21.42	7.49	3.33	13.23	14.26	27.57	40.03	50.05	57.28	49.27	39.01	24.75	347.71
Open strain	77	25.57	9.20	3.06	3.85	4.77	11.60	20.81	36.45	47.46	44.22	38.31	26.85	272.16
Lowest producing (irrespective of strain)	10	5.68	2.31	2.38	18.90	17.90	28.53	29.67	27.57	19.48	20.76	15.37	7.33	195.87
Dense-Unproductive strain	8	3.44	.17	2.31	23.19	21.65	34.09	33.98	30.45	19.53	19.99	13.80	3.95	206.54
Tree-Ripe grade:														
Highest producing (irrespective of strain)	10	6.26	2.93	2.07	1.91	1.33	3.90	9.32	13.67	13.05	10.68	10.58	8.10	83.79
Lisbon strain	22	9.67	2.96	2.59	2.63	1.32	3.84	9.16	13.66	13.32	15.52	16.50	9.31	100.50
Bull strain	11	.95	.80	1.09	.59	1.11	4.22	8.15	6.92	7.01	7.73	4.23	4.24	47.04
Sporting strain	3	3.99	2.19	1.63	1.33	.74	2.58	6.68	6.27	10.42	9.44	8.06	9.53	62.85
Entire plat	121	8.16	4.85	4.99	4.43	2.03	3.69	8.69	10.28	13.07	19.86	15.94	9.35	105.33
Open strain	77	9.67	6.57	6.86	6.03	2.60	3.97	9.53	10.92	15.16	25.10	19.15	10.97	126.54
Lowest producing (irrespective of strain)	10	2.58	3.63	1.42	1.22	.38	.60	2.18	1.90	3.21	7.39	5.74	3.40	33.66
Dense-Unproductive strain	8	.93	.04	.26	.36	.15	.16	.71	.97	1.56	1.89	2.57	.86	10.45
PERCENTAGE OF WEIGHT OF TOTAL CROP.[1]														
Green grade:														
Highest producing (irrespective of strain)	10	3.1	.9	.6	5.9	6.0	11.0	14.8	16.1	16.9	11.8	8.4	4.4	16.8
Lisbon strain	22	4.1	1.1	.5	3.4	3.8	8.5	14.0	16.7	17.8	13.6	11.3	5.1	21.6
Bull strain	11	1.2	.9	1.1	9.9	10.2	15.7	16.9	13.6	13.1	9.8	4.0	3.7	9.8
Sporting strain	3	2.4	.8	1.3	6.7	6.5	12.5	18.4	13.8	14.5	12.2	6.1	4.8	14.1
Entire plat	121	6.2	2.2	.9	3.8	4.1	7.9	11.5	14.4	16.5	14.2	11.2	7.1	26.7
Open strain	77	9.4	3.4	1.1	1.4	1.8	4.3	7.6	13.4	17.4	16.2	14.1	9.9	36.8
Lowest producing (irrespective of strain)	10	2.9	1.2	1.2	9.6	9.1	14.6	15.1	14.1	10.0	10.6	7.8	3.7	15.6
Dense-Unproductive strain	8	1.7	.1	1.1	11.2	10.5	16.5	16.5	14.7	9.5	9.7	6.7	1.9	10.4
Tree-Ripe grade:														
Highest producing (irrespective of strain)	10	7.5	3.5	2.5	2.3	1.6	4.7	11.1	16.3	15.6	12.7	12.6	9.7	33.3
Lisbon strain	22	9.6	2.9	2.6	2.6	1.3	3.8	9.1	13.6	13.3	15.4	16.4	9.3	38.2
Bull strain	11	2.0	1.7	2.3	1.3	2.4	9.0	17.3	14.7	14.9	16.4	9.0	9.0	21.7
Sporting strain	3	6.4	3.5	2.6	2.1	1.2	4.1	10.6	10.0	16.6	15.0	12.8	15.2	37.9
Entire plat	121	7.7	4.6	4.7	4.2	1.9	3.5	8.2	9.8	12.4	18.9	15.1	8.9	36.3
Open strain	77	7.6	5.2	5.4	4.8	2.1	3.1	7.5	8.6	12.0	19.8	15.1	8.7	36.6
Lowest producing (irrespective of strain)	10	7.7	10.8	4.2	3.6	1.1	1.8	6.5	5.7	9.5	21.9	17.1	10.1	45.7
Dense-Unproductive strain	8	8.9	.4	2.5	3.4	1.4	1.5	6.8	9.3	14.9	18.1	24.6	8.2	42.1

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[1] The season percentage is calculated on the production for the 4 months, May to August, inclusive.

TABLE IX.—*Diameter of rings used in picking fruits of the Green grade from the lemon trees of the Lisbon variety in the investigational performance-record plat during the 4-year period from July, 1913, to June, 1917, inclusive.*

Month.	Diameter of picking ring for Green-grade fruit (inches).				Month.	Diameter of picking ring for Green-grade fruit (inches).			
	1913-14	1914-15	1915-16	1916-17		1913-14	1914-15	1915-16	1916-17
July	$2\frac{8}{32}$	$2\frac{8}{32}$	$2\frac{8}{32}$	$2\frac{10}{32}$	January	$2\frac{8}{32}$	$2\frac{8}{32}$	$2\frac{9}{32}$	$2\frac{10}{32}$
August	$2\frac{8}{32}$	$2\frac{8}{32}$	$2\frac{8}{32}$	$2\frac{10}{32}$	February	$2\frac{8}{32}$	$2\frac{10}{32}$	$2\frac{9}{32}$	$2\frac{10}{32}$
September	$2\frac{10}{32}$	$2\frac{8}{32}$	$2\frac{10}{32}$	$2\frac{10}{32}$	March	$2\frac{10}{32}$	$2\frac{10}{32}$	$2\frac{10}{32}$	$2\frac{10}{32}$
October	$2\frac{10}{32}$	$2\frac{8}{32}$	$2\frac{10}{32}$	$2\frac{10}{32}$	April	....	....	$2\frac{10}{32}$	....
November	....	$2\frac{10}{32}$	$2\frac{10}{32}$	$2\frac{9}{32}$	May	$2\frac{8}{32}$	$2\frac{10}{32}$	$2\frac{10}{32}$	$2\frac{8}{32}$
December	$2\frac{10}{32}$	$2\frac{10}{32}$	$2\frac{10}{32}$	$2\frac{9}{32}$	June	$2\frac{8}{32}$	$2\frac{10}{32}$	$2\frac{10}{32}$	$2\frac{8}{32}$

In figure 7 the data are rearranged to show more clearly the variations between the various strains during the different months. The differences would be best illustrated by representing the production for each strain by a curve, but on account of the nature of the resulting

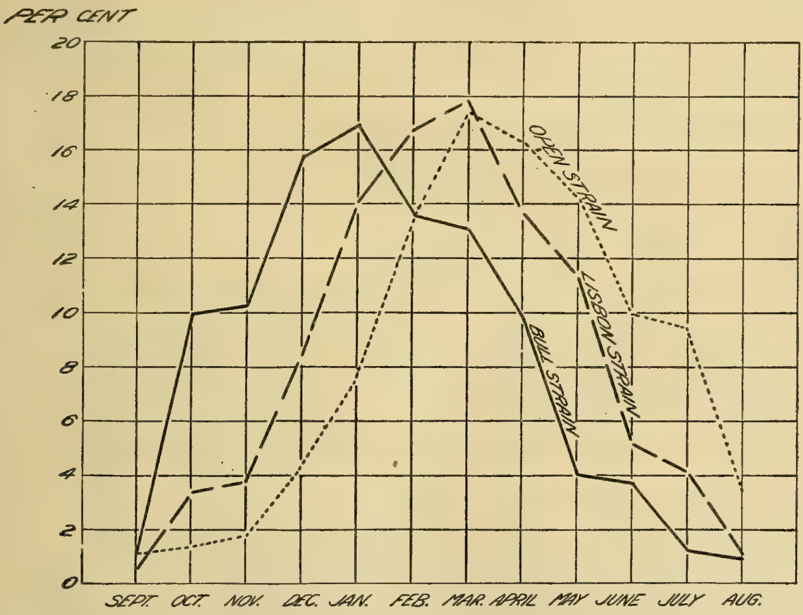

FIG. 8.—Diagram showing the percentage of the total crops of fruit of Lisbon lemons of the Green grade which were produced each month by the trees of the Lisbon, Bull, and Open strains in the investigational performance-record plat during the 3-year period from July, 1914, to June, 1917, inclusive.

curves it was impracticable to represent them all clearly on a single small-sized chart. In figure 8 are shown curves for the monthly production of the Green-grade fruit from the trees of the Lisbon, Bull, and Open strains, illustrating their variations during the season of heaviest bearing.

Further study of the seasonal variations in production from the east and west sections of the investigational plat is afforded by Table X, in which the total production at each picking period, including the fruits of the Cull grade, is expressed in terms of field picking boxes. It is interesting to study this table in the light of the data presented in Tables V and IX, showing the picking dates and the sizes of the picking rings used for fruit of the Green grade throughout the period during which these records were obtained. Such study will show the reasons for the variations stated in Table X, which at first appear to be incorrect. For example, during the first three years there is recorded a very heavy increase in yield from December to January, notwithstanding that Table V shows that the intervals between those pickings were less than 30 days. In 1916–17 there was a decrease in production at that period, although the interval between the pickings was 33 days. The explanation is found in Table IX in the use of a ring of a smaller size for the January picking during the first three seasons and the use of a larger sized ring in January, 1917.

TABLE X.—*Total fruit yields of the lemon trees of the Lisbon variety in the investigational performance-record plat for each month during the 4-year period from July, 1913, to June, 1917, inclusive.*

[The yields are expressed in terms of the number of field boxes of fruit. Records on 14 of the trees in the west section of the plat were begun in July, 1914. Eleven of these trees were of the Bull strain.]

Month.	Number of field boxes of fruit produced.						
	East section of plat, 106 trees.				West section of plat, 15 trees.		
	1913–14	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17
July	61½	43½	184	59½	2	6¾	4
August	32½	12½	73½	12	....	3¼	½
September	11	15¾	66	11½	6¾	3	2
October	46	48½	26	27	36	2½	14
November	....	47¾	22	21	19½	9½	25½
December	60	79	57½	53	20	24½	29½
January	200	179	105¾	45½	48	36	16½
February	409	206½	113	192	28	27½	34½
March	204	246	113¾	235	39	25	28
April	....	....	140½	....	29½	34½	....
May	186	479	117¾	397	....	12	....
June	70	237	88½	57½	25	10½	35½
Total	1,279	1,594½	1,108¼	1,111	253¾	195	190
Heaviest	February	March	April	March	January	January	February.
Lightest	September	August	November	September	July	October	August.

Similarly, Table X shows a decrease in yield from February to March, 1914, with a picking interval of 36 days, and practically no change in the production for that period in 1916, with a picking interval of 30 days, while there was an increase in the crops for that month in 1915 and 1917, with picking intervals of 21 and 33 days, respectively. Table IX shows that a change was made in March, 1914, and

1916, to a picking ring of a larger size, while in 1915 and 1917 no change was made at that time.

The variations in the production of fruit of the Green and Tree-Ripe grades by the trees of the various strains is very forcibly illustrated in Table XI. The average yield for the 3-year period as given in Table VIII is calculated to the acre basis and expressed in terms of packed boxes. This indicates a yield of 585 packed boxes per acre by the 10 highest producing trees, as opposed to 196 packed boxes per acre by the 10 lowest producing trees. The trees of the Lisbon strain show a production at the rate of 542 packed boxes per acre, while the trees of the Dense-Unproductive strain would have borne only 186 packed boxes per acre. The average yield of the 10 highest producing trees was 51 per cent higher than the average for the entire plat, while the average of the 10 lowest producing trees was only 48 per cent of the average of the plat as a whole, or 32 per cent of the average produced by the 10 highest yielding trees.

TABLE XI.—*Annual yields and calculated production per acre of fruit of the Green and Tree-Ripe grades picked from the lemon trees of the various strains of the Lisbon variety in the investigational performance-record plat for the 3-year period from July, 1914, to June, 1917, inclusive, as shown in Table VIII.*

Number of trees.	Description of trees.	Average annual production, 3-year period.					
		Production per tree (pounds).		Calculated production per acre (packed boxes).			Percentage of average of plat.
		Green grade.	Tree-Ripe grade.	Green grade.	Tree-Ripe grade.	Total.	
10	Highest producing (irrespective of strain)	599.75	83.79	513.12	71.69	584.81	150.88
22	Lisbon strain	532.86	100.50	455.89	85.98	541.87	139.80
11	Bull strain	568.85	47.07	486.68	40.25	526.93	135.94
3	Sporting strain	494.72	62.85	423.26	53.77	477.03	123.07
121	Entire plat	347.71	105.33	297.49	90.12	387.61	....
77	Open strain	272.16	126.54	232.85	108.26	341.11	88.00
10	Lowest producing (irrespective of strain)	195.87	33.66	167.58	28.80	196.38	50.66
8	Dense-Unproductive strain	206.54	10.45	176.71	8.94	185.65	47.90

The average weight per fruit for the total production of fruit of the Green and Tree-Ripe grades from the trees of the various strains in the Lisbon plat is shown in Table XII, and the average weight per fruit of the two grades combined is presented graphically in figure 9. The trees of the Open strain are shown to have produced fruit of the lightest weight, except that the lightest fruits of the Tree-Ripe grade borne by the trees of any strain were from the 10 lowest producing trees, which include the 8 Dense-Unproductive ones and the 2 lowest producing trees of the Open strain. The trees of the Bull strain produced the heaviest green fruit and the heaviest average weight of the combined grades. These trees also bear very large crops, averaging only slightly below the trees of the Lisbon strain in the investigational plat. This combination of high production and heavy individual fruits which grow very rapidly and are thick skinned is probably due, in part at least, to the excessively vigorous and rapid growth of the trees of this strain.

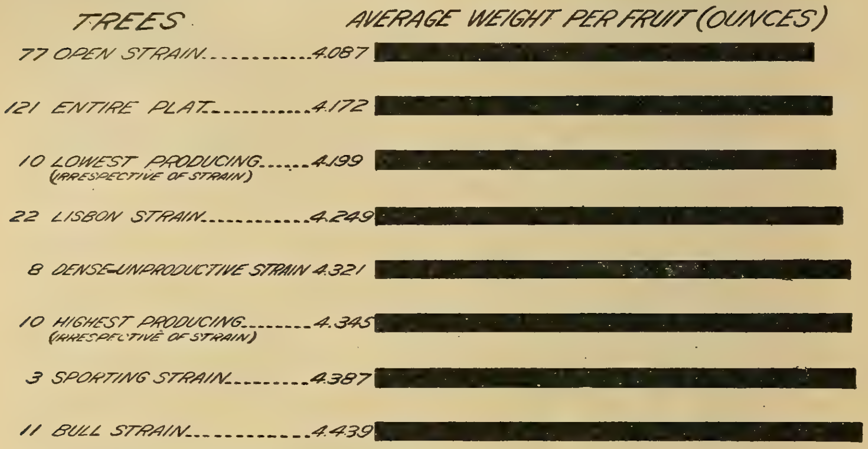

FIG. 9.—Diagram showing the average weight per fruit of the Lisbon lemon of the Green and Tree-Ripe grades borne by the trees of the various strains occurring in the investigational performance-record plat. These weights are expressed in ounces and are based on data for the 4-year period from July, 1913, to June, 1917, inclusive, except as noted in Table I.

Figure 10 shows the average seed content of the fruits of the various strains in the Lisbon investigational plat. The fruits of the Open strain averaged 5.07 seeds, while those of the Dense-Unproductive strain averaged only 1.67 seeds. The data show that a seed content of about 4.39 is characteristic of the Lisbon strain.

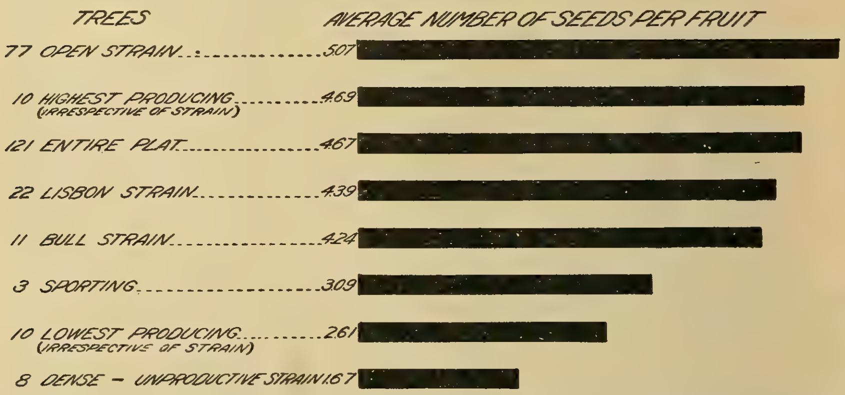

FIG. 10.—Diagram showing the average number of seeds per fruit found on lemon trees of various strains of the Lisbon variety in the investigational performance-record plat. This is a summary of the data recorded during the 3-year period from July, 1913, to June, 1916, inclusive, except as noted in Table XI.

TABLE XII.—*Average weight per fruit for lemons of the Green and Tree-Ripe grades produced by the trees of the various strains of the Lisbon lemon in the investigational performance-record plat.*

[These data cover the 4-year period from July, 1913, to June, 1917, inclusive, except as noted in Table I.]

Number of trees.	Description of trees.	Average weight per fruit (ounces).		
		Green grade.	Tree-Ripe grade.	Both grades.
77	Open strain	4.317	3.573	4.087
121	Entire plat	4.348	3.616	4.172
10	Lowest producing (irrespective of strain)	4.330	3.534	4.199
22	Lisbon strain	4.351	3.706	4.249
8	Dense-Unproductive strain	4.350	3.804	4.321
10	Highest producing (irrespective of strain)	4.415	3.849	4.345
3	Sporting strain	4.428	4.052	4.387
11	Bull strain	4.479	4.007	4.439

The variations in seed content in the several Lisbon strains from month to month throughout the year are presented in Table XIII and the data for the Open, Lisbon, and Dense-Unproductive strains are shown graphically in figure 11. The irregularities for November and April are probably accounted for by the fact that owing to interference of one sort or another records are available for only two seasons in November and for one season in April. The periods of lightest and heaviest crop production are known to vary somewhat from year to year, as already shown, and it is believed that in the same manner the seasons of high and low seed content fluctuate in different years. Hence, with records for only two years for November and one year for April, while the other months are represented by data for three years, it is quite probable that the relative variations as shown are somewhat incorrect.

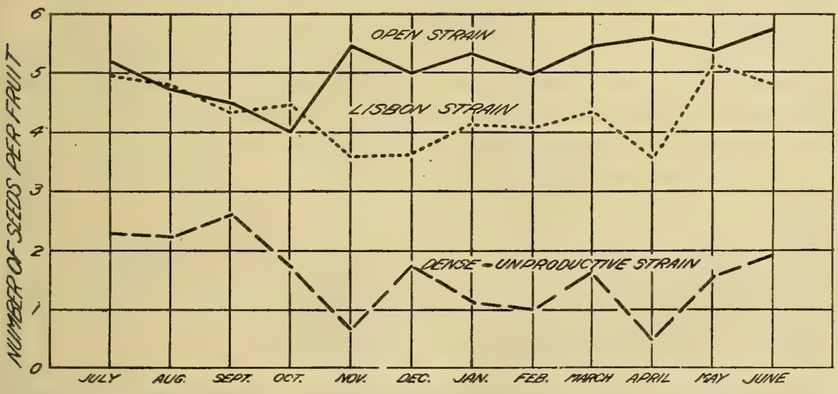

FIG. 11.—Diagram showing the average number of seeds per fruit of some of the strains of the Lisbon lemon found each month on trees in the investigational performance-record plat during the 3-year period from July, 1913, to June, 1916, inclusive.

TABLE XIII.—*Average number of seeds per fruit picked from lemon trees of the various strains of the Lisbon variety in the investigational performance-record plat during each month of the 3-year period from July, 1913, to June, 1916, inclusive.*

[The trees of the Bull strain and three other trees, indicated in Table I, were added to the plat in 1914, so that the records here presented for those trees cover the 2-year period from July, 1914, to June, 1916, inclusive.]

Number of trees.	Description of trees.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	For the period.
77	Open strain	5.20	4.73	4.50	4.00	5.45	5.01	5.33	4.99	5.46	5.57	5.38	5.73	5.07
10	Highest producing (irrespective of strain)	4.96	4.13	4.44	5.05	4.24	4.45	3.87	4.14	4.93	3.60	5.77	5.73	4.69
121	Entire plat	4.92	4.60	4.26	3.95	4.64	4.42	4.78	4.53	4.95	4.60	5.03	5.23	4.67
22	Lisbon strain	4.95	4.80	4.33	4.45	3.58	3.63	4.14	4.09	4.36	3.53	5.11	4.81	4.39
11	Bull strain	4.98	2.79	3.73	4.03	2.69	3.34	4.05	4.41	4.84	3.12	5.53	5.59	4.24
3	Sporting strain	3.43	3.60	1.75	3.14	3.69	3.46	3.52	3.71	3.00	3.75	2.60	2.29	3.09
10	Lowest producing (irrespective of strain)	3.04	3.47	3.21	2.06	2.30	2.45	2.39	2.08	3.20	1.90	2.40	2.62	2.61
8	Dense - Unproductive strain	2.29	2.24	2.62	1.73	.68	1.73	1.15	1.00	1.63	.52	1.56	1.92	1.67

COMPARATIVE VALUE OF THE STRAINS.

The individual-tree performance-record studies of the Lisbon lemon variety have shown that only two strains are of commercial value. These are the Lisbon strain and the Open strain. Trees of the Lisbon strain are very productive and commonly bear most of their crop during the spring months. The trees are hardy and more or less resistant to unfavorable climatic conditions. For this reason in particular the Lisbon strain seems to be well adapted for locations exposed to strong winds or where high or low temperatures or other extreme climatic influences are likely to affect the production of the trees.

The production of heavy crops by the trees of the Lisbon strain under normal conditions during the early spring months frequently necessitates holding much of the fruit in storage until the late summer or fall. However, the vigorous growth characteristic of the trees, the protection of the lemons in the trees by the rather dense foliage, and the fine quality of the fruits are factors which must be taken into consideration by citrus growers.

The trees of the Open strain of the Lisbon variety have the habit of producing more or less regular crops throughout all seasons of the year. While this characteristic is not so marked as in the case of the trees of the Eureka strain of the Eureka variety, it is very striking when compared with the behavior of the trees of the Lisbon strain. The crops from the trees of the Open strain, while not as great as those of the Lisbon strain for the entire year, are likely to be more valuable, because they are produced more heavily during the seasons when the market is usually the best and lemons bring the highest prices. The fruits of the trees of the Open strain are not as well protected from sun and temperature injuries, nor are the trees apparently as hardy as those of the Lisbon strain. For certain conditions, however, it seems probable that the Open strain is the most valuable one for commercial lemon production. The trees of the Open strain have fewer and smaller thorns and the fruits are more easily picked than those of the Lisbon strain.

THE UNINTENTIONAL PROPAGATION OF UNDESIRABLE STRAINS.

In the earlier stages of the lemon industry in California propagators considered fruit characteristics as a definite measure of the value of parent trees for bud wood. Later, the importance of the fruits in the selection of parent trees as sources of bud wood was entirely lost sight of. Bud wood was taken wherever it could be secured with a minimum of time, labor, and expense. As a result, it was frequently procured from vigorous-growing trees of vegetative strains, which often are least productive and least desirable. Some propagators, believing that the size of the tree was correlated with production, when cutting bud wood secured it from the largest trees in the orchard. Nurserymen often cut bud wood from trees in the nursery rows or from sucker growth on fruiting trees. The result of these various practices was the unintentional propagation of many worthless strains.

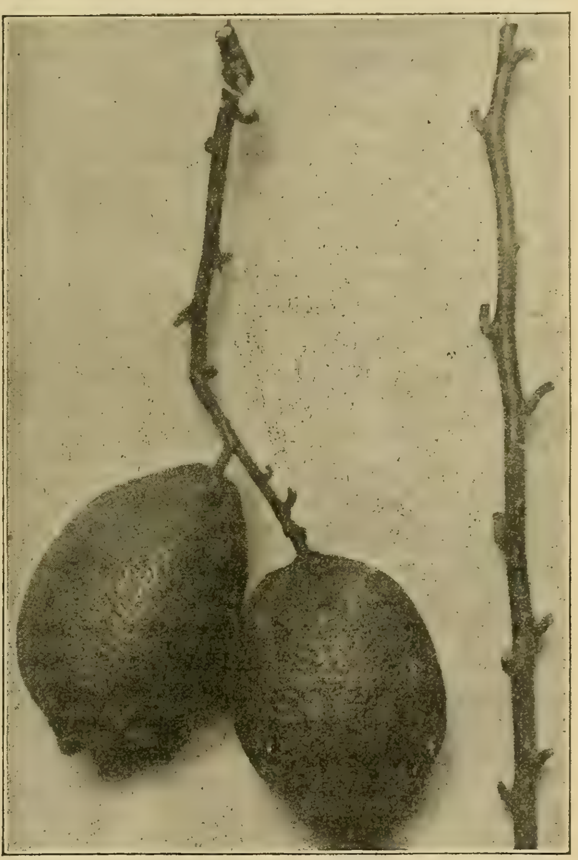

FIG. 12.—Fruit-bearing lemon bud wood with typical fruits attached to one stick. The bud sticks, after being cut and trimmed, should be packed in slightly moistened sphagnum moss and held in a cool room until needed for use.

In the course of these investigations the method of using fruit-bearing bud wood, as shown in figure 12, has been evolved. The use of fruit-bearing bud wood with the fruits attached has largely eliminated the danger of the unintentional propagation of worthless strains of the Lisbon lemon. When such bud wood is used it naturally results in its being obtained from the most heavily fruited trees, as these trees have more available fruit wood than trees of vegetative or poor-fruited strains. When bud wood is taken from fruit-bearing wood of performance-record trees the danger of propagating undesirable strains is greatly reduced.

THE ISOLATION OF STRAINS THROUGH BUD SELECTION.

The orchards of the Lisbon lemon variety include trees of many diverse strains which have originated from bud variations. In this bulletin the description and characteristics of some of the important strains are presented. Some of these strains, on account of their low and inferior production, are not worthy of propagation. Other strains produce fruits low in acidity, with little or no juice, of undesirable shapes, of coarse texture, or with some other undesirable characteristic. A mixture of strains in any commercial orchard is undesirable and is likely to depreciate the value of the orchard.

The first step in these investigations was the determination of the relative value of the different strains of the Lisbon lemon for commercial production in California. The next step was the isolation of the important strains through bud selection. This was accomplished by propagating from performance-record trees those which were typical of the different strains and in this propagation using only fruit-bearing bud wood with typical fruits attached to the bud stick. The oldest trees which have been propagated from typical trees in the performance-record plats are now 5 years old from time of planting. The young trees are now bearing commercial crops of fruit, and performance records are being obtained from many of them.

While the progeny data obtained are incomplete as yet, a sufficient amount of information has already been secured to warrant the statement that each of the important strains of the Lisbon variety has been isolated through careful bud selection. This does not mean that individual tree variations are not encountered in these young trees, because variations within the strains are found which are similar in degree to those of the parent trees. However, there has been no mixture of strains, and in every case the same differences which characterize the parent trees are found in their progenies.

TOP-WORKING UNDESIRABLE LEMON TREES.

The investigations have shown that in many lemon orchards there are a number of healthy unproductive trees of undesirable strains. These unproductive trees usually can be successfully top-worked by using bud wood selected from fruit-bearing wood on superior performance-record trees. Figure 12 shows typical fruit-bearing lemon bud sticks after they have been removed from the tree and are trimmed ready for use.

While it is possible to practice top-working during quite a long season, commercially it is usually done through the months of April, May, and June. In the course of these investigations it has been demonstrated that the best results have been secured during May and early June. Previous to top-working, the trees should be pruned, so

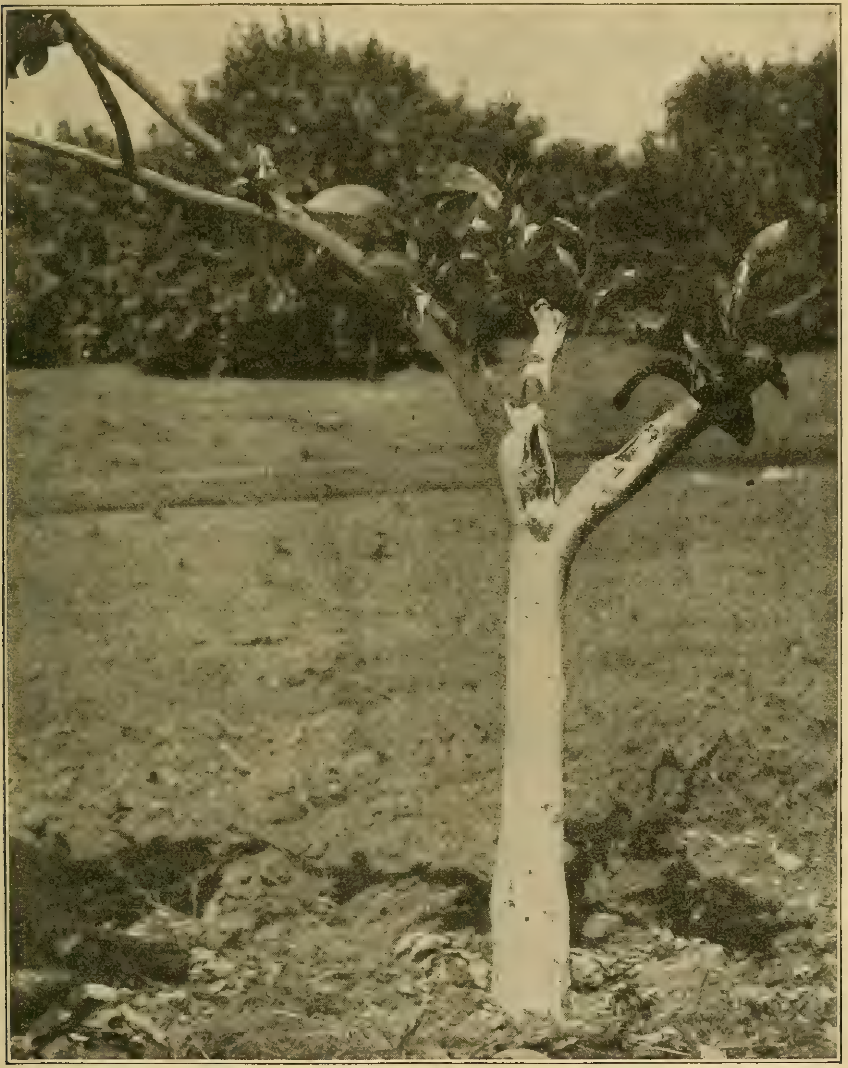

FIG. 13.—Unproductive lemon tree of the Villa Franca variety top-worked with fruit-bearing bud wood of the Lisbon strain. The nurse limb shown at the left was allowed to remain for one year. The photograph was taken two months after the buds were inserted.

as to allow free access to the limbs in which the buds are to be placed. Usually from three to five strong limbs should be selected which can furnish the framework for the new top. The buds should be inserted in the limbs from 1 to 2 feet from the forks. Two buds are generally placed in each limb, and as one of these buds is likely to develop if this method is followed a perfect stand usually can be obtained. In about 10 days or two weeks after the buds have been inserted they will form a union with the limbs and the wounds will

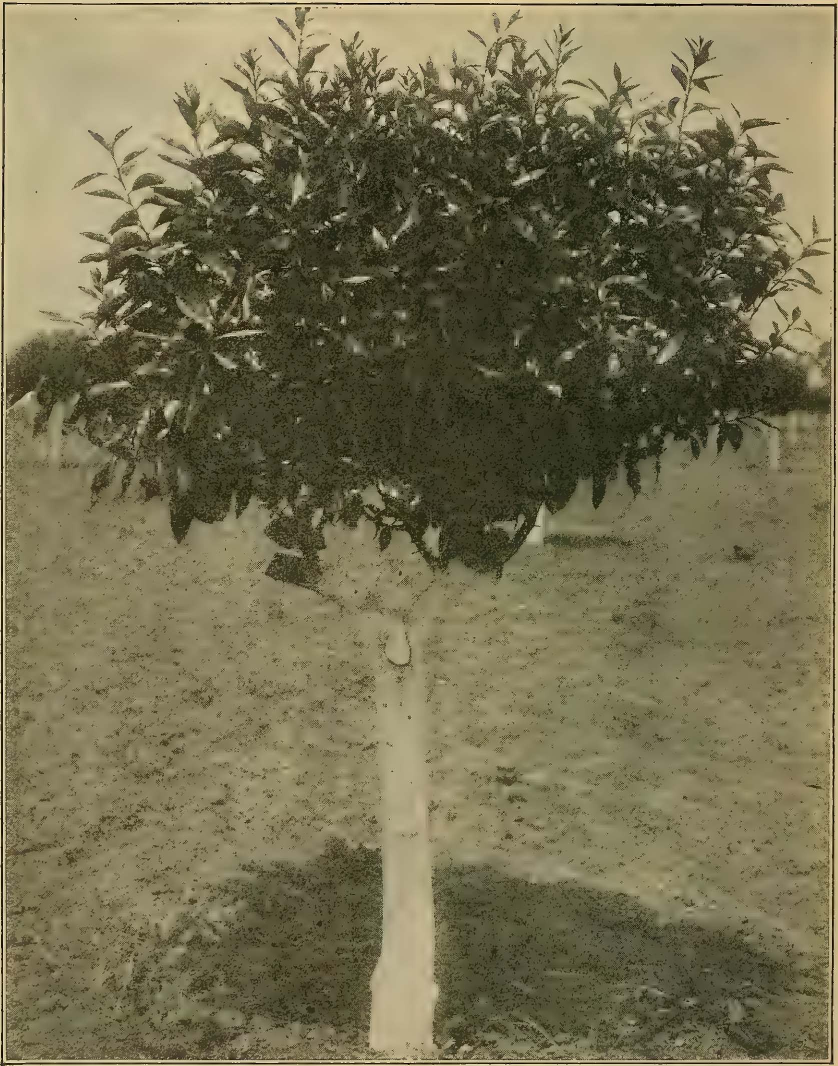

FIG. 14.—Unproductive lemon tree of the Villa Franca variety top-worked with buds of the Lisbon strain. The photograph was taken one year after the budding was done and soon afterwards the main framework limbs were again cut back and only one growth from the rebuds was left on each limb. This tree and the one shown in figure 13 are in the same orchard and were top-worked at the same time.

have healed. The limbs should then be cut off about 6 inches above the buds and all other branches removed from the tree. In some instances, as shown in figure 13, one limb of the original top, known as a nurse limb, is allowed to remain in order to preserve somewhat the balance of the tree. It is questionable, however, whether anything is gained when this method is followed, as just as good results have been observed in the course of these investigations where all the limbs are cut back to a point about 6 inches above the buds. The cut surface should be immediately covered with grafting wax, asphaltum, or some other protective material. The trunk and main branches are protected from sun injuries by a coat of whitewash.

An unproductive tree of the Villa Franca variety which has been top-worked with bud wood from a productive tree of the Lisbon strain is shown in figure 14. This tree is comparable with the one shown in figure 13, with the exception that the young top represents 10 months' growth. In about a year from budding, or when the tree is in the condition shown in figure 14, the stubs of the rebudded limbs should be cut back again, making a smooth, sloping cut, and leaving only one sprout from one bud on each limb. The cut surfaces should be covered with grafting wax or some similar material. The young top-worked trees must be closely watched for several years and all sprouts from below the buds removed; if not, the young top will include branches from the original unproductive top and the whole object of top-working will be defeated. Under normal conditions the top-worked tree with selected buds from superior parent trees should begin bearing the second year after rebudding, and in the third and fourth years should bear good commercial crops.

REPLACING UNDESIRABLE TREES IN BEARING ORCHARDS.

In many old bearing orchards undesirable or unhealthy trees are frequently found, and it is often more economical to replace these trees with younger ones from selected buds rather than to top-work them. Owing to lack of attention to details, until quite recently it had been generally assumed that such replanting would prove unsuccessful. Experience has shown, however, that when proper care is used undesirable lemon trees in old orchards can be replaced with young trees grown from selected buds.

The undesirable or diseased trees should be removed from the orchard during the late summer or early fall, and immediately after the older trees have been taken out holes should be dug for the new trees. These should be at least 5 feet in diameter and from 2 to 3 feet in depth. The holes should then be filled with good topsoil which has been mixed with well-rotted manure. The loose soil and manure should be allowed to settle in the holes during the winter and early-spring months. In placing the soil in the holes a sufficient quantity should be provided so that in the spring the soil will stand at least 6 to 8 inches above the land in the orchard. This will provide for any future settling.

In the spring the young trees are planted in the place thus provided for them. Especial care must be used to provide sufficient water for them at each irrigation, which is often accomplished by making an irrigation furrow at the side, or frequently by making a basin around each tree. Small applications of a quickly available nitrogenous fertilizer, if applied to the young trees, often stimulate early growth. When care is exercised in properly preparing the holes for the trees, in furnishing adequate irrigation water, and in distributing additional fertilizer if needed, the replanted trees in an old bearing orchard will make as good a growth as if planted as solid blocks of trees in a new orchard.

THE SELECTION AND CARE OF BUD WOOD.

Bud wood should be taken only from fruit-bearing wood on performance-record trees. In addition to the performance records, the propagator should have an intimate knowledge of the behavior of the individual tree. This can be obtained only by careful studie of the variety and strain which he desires to propagate. The lemons which are attached to the bud sticks can be used as an indication of the type of fruit which the buds on the sticks will produce. The use of this type of bud wood guards against taking wood from sporting or undesirable branches.

Plate VIII shows two variations found on separate branches in a lemon tree on which all the other fruits were of the Lisbon strain. By using buds taken from sticks with the fruits attached the danger of propagating these undesirable variations is eliminated. If this type of bud wood is used, more buds can be cut from productive trees than from unproductive ones.

Enough experimental and practical evidence has already been collected in the course of these investigations to show that fruit-bearing bud wood from productive trees is the most desirable kind to use for propagation. Nursery trees from this type of wood make a very vigorous growth and come into early fruiting. After the bud sticks are cut the leaves are removed, as shown in figure 12, and the sticks from each tree are tied in separate packages, with the number of the tree marked on the end of one of the bud sticks and also on a wooden or other suitable label which is tied to the bundle. In this way the progeny of each parent tree can be kept separate. As soon as the bud sticks are labeled they should be wrapped in moist sphagnum moss or some other suitable material. If it is necessary to store the bud sticks for any length of time they can be put in a cool room where the temperature is about 70° F. and does not fluctuate greatly.

As a result of the citrus-fruit improvement investigations, in May, 1917, the California Fruit Growers' Exchange, a cooperative organization of about 8,000 citrus growers, inaugurated a bud-supply department, which was established as a public service, its purpose being to furnish bud wood from performance-record trees of all the important California citrus varieties to growers and nurserymen. As this department was established for the good of the whole citrus industry its privileges are not restricted to members of the exchange, but buds are distributed at cost to all who apply for them. Buds are cut only from trees on which performance records have been obtained for several years. These trees are located in orchards which are well-known producers of superior crops of valuable fruits. The purchaser, if he cares to do so, has the opportunity of visiting the individual parent trees in the orchards from which the buds come, and he can inspect the records and examine the fruits of these trees. Only fruit-bearing bud wood is used, and the fruits from the bud sticks are returned to the owner of the trees. Each lot of bud sticks is kept separate and is labeled with the number of the parent tree or with a key number. The grower or nurseryman receiving the buds therefore can keep the progeny of each parent tree separate. Men who have been thoroughly trained and have an intimate knowledge of the important variations in the standard citrus varieties are exclusively employed for this work. In this way the industry is distributing wood of the best lemon strains only, and it is reasonable to expect that the young orchards which are planted with trees propagated from this type of bud wood, and older orchards which are top-worked, will eventually bear the best type and quality of fruit.

SUMMARY.

The important commercial lemon varieties now grown in California are the Eureka and Lisbon. The Lisbon variety was introduced from Australia about 1874, and later in 1875, with perhaps less-important later introductions.

Several important strains of these varieties have resulted through the unintentional propagation of bud variations. In this bulletin only the variations within the Lisbon variety are discussed. Descriptions of variations in the Eureka variety will be found in United States Department of Agriculture Bulletin No. 813.

Bud variations are of frequent occurrence in some of the trees of the Lisbon variety. Some of the strains which have developed from them are inferior in quality and quantity of fruit and mature the fruits at seasons when there is no great market demand for them. These strains occur as variations in the habit of tree growth, in characteristics of the foliage and blossom, and in the color, shape, texture, juiciness, and other characteristics of the fruit.

The object of these investigations has been to determine the behavior of trees of the different strains and of the individual-tree variations within the strain, to prevent the propagation of inferior strains, to develop practical methods for eliminating undesirable trees in established orchards, and to isolate and propagate the desirable strains and superior trees within these strains through bud selection based on individual-tree performance records and intimate tree knowledge.

The plan of work as followed in these investigations has been to secure individual-tree performance records in carefully selected plats of the Lisbon variety. Each tree is picked separately, the fruits assorted, counted, weighed, detailed notes taken, and other data obtained, so that after a series of years definite conclusions concerning strains and individual-tree behavior can be drawn.

In these investigations five strains of the Lisbon lemon have been studied, their characteristics described, and the performance records of individual trees recorded.

Some of the lessons taught by these studies include the discovery of the importance of bud variations, the comparative value of the different strains arising from them, the need of eliminating the unprofitable strains and isolating the valuable ones through bud selection, and the origination and introduction of improved methods of propagation for conserving and improving the production of the Lisbon lemon variety. The desirable strains can be isolated by means of careful bud selection based on individual-tree performance records and intimate tree knowledge.

Undesirable healthy trees or inherently unproductive ones in established orchards usually can be successfully top-worked by using select fruit-bearing bud wood from performance-record trees.

Undesirable unhealthy trees in old-established orchards can be replaced with desirable younger trees which have been propagated from selected fruit wood, provided proper attention is given to the preparation of the planting hole and, later, to care in irrigation and fertilization.

Only fruit-bearing bud wood from superior parent trees which have been selected on the basis of their performance records and from intimate tree knowledge should be used for propagation or for top-working.

The California Fruit Growers' Exchange, a cooperative organization of 8,000 citrus growers, has established a bud-supply department as a result of these investigations. This department furnishes at cost to growers and nurserymen bud wood from superior performance-record trees.

UNITED STATES DEPARTMENT OF AGRICULTURE

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WM. A. TAYLOR, Chief

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STREET TREES.

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IMPORTANCE OF SHADE TREES.

THE COMFORT to be derived from shade trees has long been recognized. The early settlers of this country saved fine trees about their homes, on the village greens, along the country roads, and in the fields. Later, as villages grew, the householders planted trees adjoining their properties, and the result has been the beautiful elm-shaded villages of New England, the maple-shaded towns of New York and the Ohio Valley, and the oak-shaded streets of the Southeastern States. (Fig. 1.)

With time, the villages and towns became cities, and the woodlands were largely destroyed. Conditions for tree growth were less favorable in the cities, and nurseries had to be depended upon for planting material. With these changed conditions the native trees of a region became less dominant in the city planting and were largely replaced by those trees listed in nursery catalogues which took the fancy of each property owner along the street. (Fig. 2.) The quickest growing trees were considered first, and as some of these made a big showing the first few years and were easily transplanted, they have become the dominating trees in street planting from the

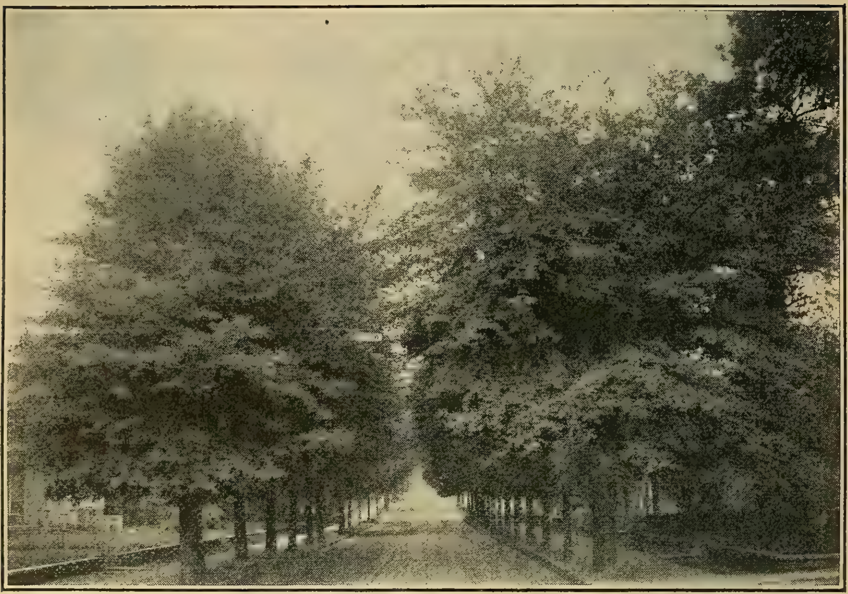

FIG. 1.—An oak-shaded street in the South. Willow oaks in Birmingham, Ala., in late summer.

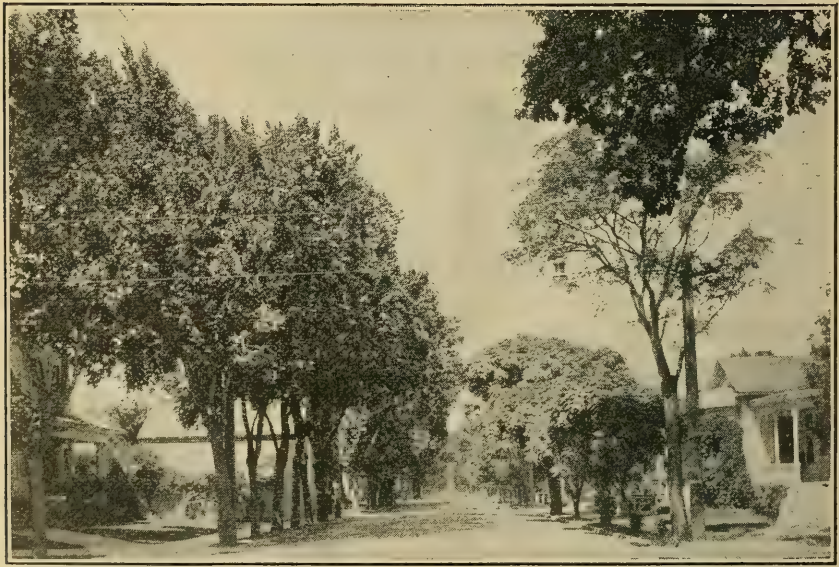

FIG. 2.—A street with mixed plantings. The trees are of different kinds, some unsuited for the purpose, planted at varying distances apart, according to the inclination of the property holders. A street in Stockton, Calif., photographed in early summer.

Atlantic to the Pacific and from the Great Lakes to the Gulf of Mexico. (Figs. 2, 10, and 13.) A few have planted better and more lasting trees (figs. 1, 3, and 4); but the tree growth on the streets of the average town or city is ragged and unkempt in appearance, while that of the suburb or small village is not much better unless the planting has been done under municipal control and the plantings on a street have been confined to a single kind of tree.

The advent of such civilizing agencies as the telegraph, the telephone, the electric light, and the trolley car have added each its share toward the mutilation or destruction of the good trees that were in existence at the time of their coming. Faulty methods of pruning also have caused much disfigurement and ruin. (Figs. 5 and 21.) To this mutilation has been added the unnecessary destruction of many trees in centers of business (fig. 6), because they excluded a little daylight, or made a store less prominent, or were somewhat in the way of using the sidewalk for merchandise.

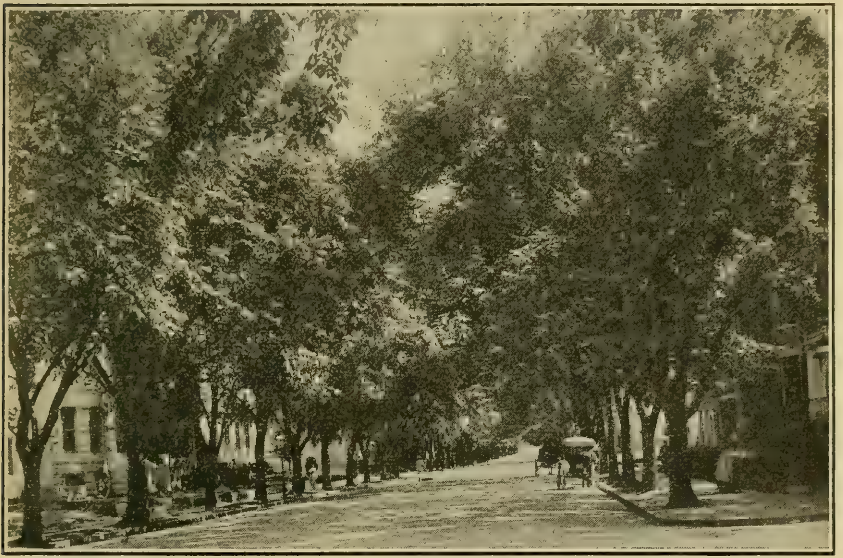
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FIG. 3.—American elms on a city street in midsummer. All these trees were planted at one time at uniform distances apart by the Commissioners of Washington, D. C.

In spite of all these troubles tree planting has continued because people love trees, enjoy well-shaded streets, and are willing to make efforts to get them. The trees on well-shaded streets are not only pleasing, but also contribute toward the health of the community by transpiring moisture into the atmosphere and by producing a restful effect on eyes and nerves. Red, especially, is known to have an exciting effect on human beings, and where city streets are well shaded it makes less prominent those colors that might otherwise prevail and offend.

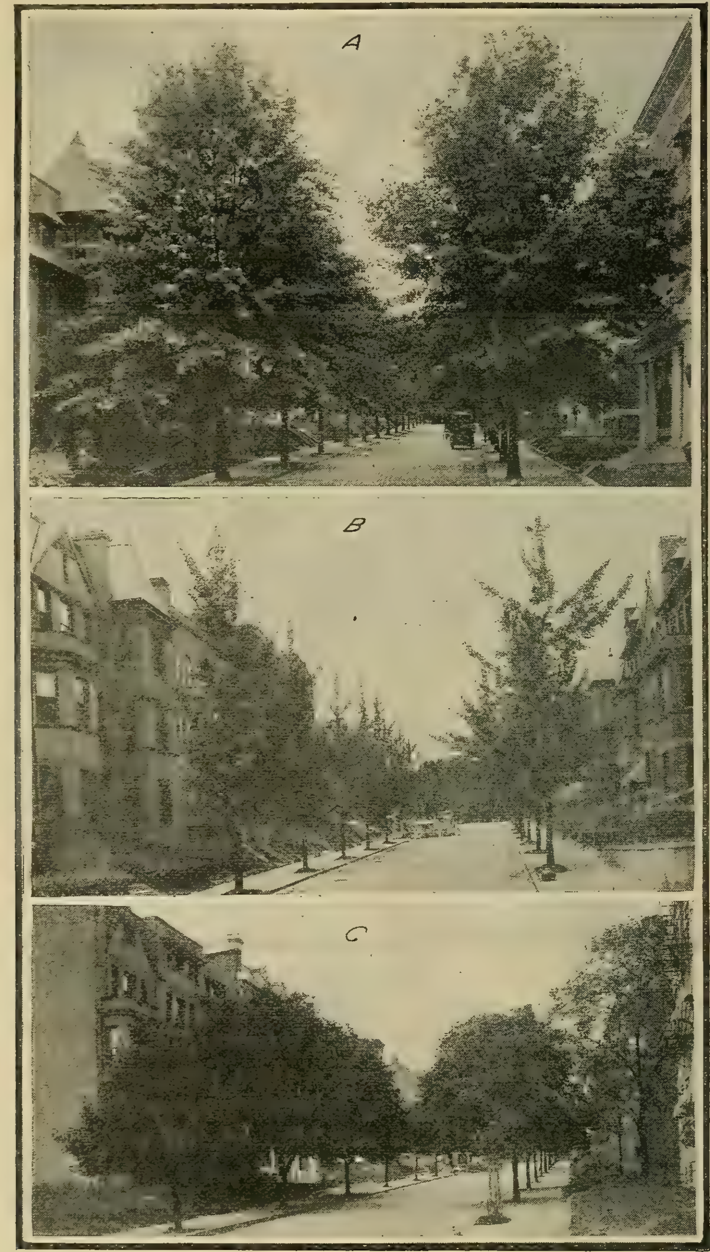

FIG. 4.—Trees 18 years old on adjacent streets: *A*, Pin oaks; *B*, ginkgos; *C*, Norway maples. Note the differences in size.

Good shade is so appreciated that its presence adds a value to adjoining properties. Real-estate men recognize this factor and plant shade trees as early as practicable on land which they develop. That the beauty of a city is improved by good street trees is becoming recognized more and more and is finding expression in the desire of garden clubs, civic improvement associations, and boards of trade for information on this subject.

Success in planting street trees can be attained only by planning and controlling the planting as a whole, by selecting the most suitable varieties, by securing trees in the best condition and planting them properly, and by giving the necessary later care.

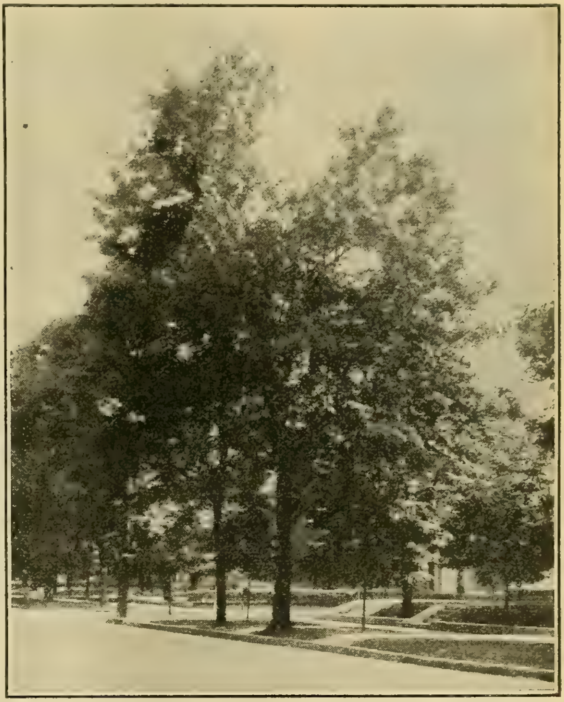

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FIG. 5.—A tree mutilated by linemen. An otherwise beautiful red oak in Louisville, Ky., as it appeared in midsummer.

While towns were small, conditions for tree growth favorable, and woodlands plenty, so that native trees were easily obtained and started, the practice of each householder planting his own trees as he saw fit gave good results. As towns became larger and impervious pavements took the place of earth roads, the conditions for tree growth became more severe and the results from the individual planting of trees less uniform. In large cities the conditions to be met are so extreme that it has become practically impossible for the average householder to grow street trees successfully, or to do so only at excessive cost. Then, too, a lineman in a few minutes often undoes what the individual has achieved with care and years of patient waiting (see fig. 5). The trees and the lines are both needed by the public, but when provided by individual initiative at private expense, but trimmed for the benefit of electric lines by employees of corporations intent on maintaining service at the least cost, the trees suffer unduly.

In order to have good shade trees at a reasonable cost which receive timely and efficient attention, with the effective control of wire lines, the care of the trees needs to be vested in some adequate authority.

PUBLIC CONTROL OF STREET TREES.

Providing shade on city streets is as much a municipal function as providing lights or sidewalks and should, therefore, be cared for by public officials. All street trees should be directly under the care of duly appointed officers, who should be responsible for their planting and care, as well as for their pruning or removal. Negative control by requiring permits for planting, pruning, and removal is little better than no control.

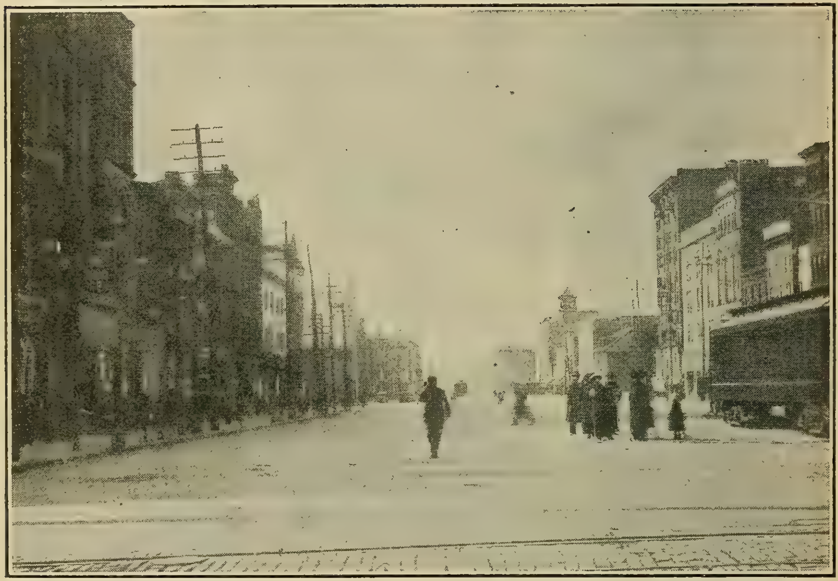
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FIG. 6.—A desert of asphalt in the business center of a city having less than 100,000 population.

The officials in charge should have the necessary authority and should be required to initiate and carry forward planting and all other needed work connected with the establishment and maintenance of street trees. Probably the most satisfactory way of securing supervision is through an unpaid commission of three or five members, which in turn employs an executive officer. In a small place a commission of three persons may be best, one being appointed every 2 years for a 6-year term. In large places five members may be better, and the ideal term would be 10 years. A compromise would be a 5-year term, a new member being appointed each year. The great need of long-term appointees is that it takes two or three years for a member of such a board or commission to see and realize the things needed to be done and the policies that should be carried out. Because it takes a long time to get results in growing street trees, the policies should be as nearly continuous as possible and the terms of the members long enough to insure a majority of experienced persons on the board at all times.

The method of appointing the commissioners is not so important as that each shall be selected from the territory as a whole rather than from a part of it. In some places where the term of service is 10 years, each one's successor is appointed by the remaining commissioners, subject to confirmation by the court. Where this is done a member is not permitted to succeed himself. In other places the commission is appointed by the court; in others, it is elected by the city legislative body or is appointed by the mayor subject to the approval of the legislative body. The important point is to keep the administration as nearly as possible on a purely business basis.

A good board can accomplish nothing without liberal funds. There are two methods of providing these: (1) By an appropriation from the general tax levy and (2) by direct assessment against the properties, collectible with the other taxes. If the funds are provided by appropriation, a fixed minimum, expressed in millage of the tax rate, should be provided in the organization of the commission. This minimum should be such that a fair amount of maintenance work can be done when no other funds are available. Councils that appropriate money sometimes hamper boards by withholding appropriations. Work of the nature of tree planting should not be permitted to suffer or be lost by a year's neglect. The fund provided by this minimum amount should not be so large that regular additional appropriations will not be needed to carry on the work properly, as this will give a desirable point of contact of the commission or board with the ordinary channels of expressing public sentiment in the district interested. The minimum appropriation mandatory should be sufficient to prevent injury from lack of care of work already begun. A period of minimum care and attention while a board and the people or their representatives are coming to a new understanding of one another's position is not necessarily a detriment, provided a reasonable maintenance has been possible in the interim, but without such care the results are ruinous and work would better not be started than be undertaken with the possibility of such a period of neglect occurring.

It is probably desirable to assess the cost of tree planting against the adjacent property owners at a proportional cost per front foot and to provide for maintenance out of a general fund. Boulevards and other unusual developments are sometimes maintained with satisfactory results by regular assessments against the abutting properties.

After a proper governing board is provided, the securing of a competent executive is a matter of ordinary business procedure. It is usually desirable that he shall be not only a good executive but also a man with a knowledge of trees and trained in their care, so that he may be a competent adviser of the board as well as its executive.

PLANNING FOR TREES ON CITY STREETS.

With the help of one who knows trees and the local conditions to be met, the town should be studied and a suitable kind of tree selected for each street or for a large portion of a street (figs. 1 and 3), and as conditions warrant the plan should be carried out as outlined. Mixed plantings of different sorts of trees (figs. 2 and 7) are not as pleasing and effective as the use of a single species for considerable distances. The use of only one or two kinds for a whole town is likely to be monotonous, and it is also undesirable because the variety most used may become subject to serious disease or insect attacks. The species and varieties of trees suitable for city planting are few enough, if all are used, so an endeavor should be made to include as many different kinds as practicable, assigning one variety for a long stretch of street unless there is a marked change in its character, in which case a change of trees would be warranted.

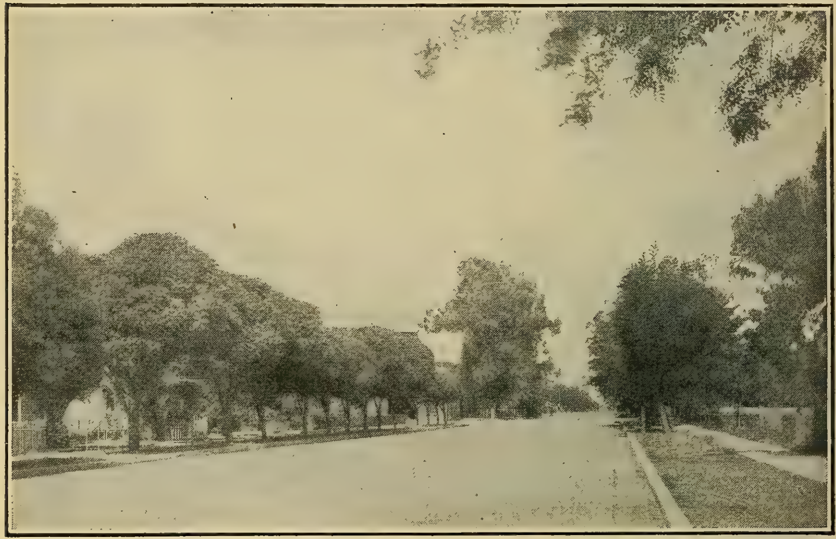
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FIG. 7.—Increased attractiveness due to trees on a city street, as shown by contrasting the two sides of the thoroughfare. If trees like red oaks, American elms, or the Eucalyptus in the distance had been used, the effect on this wide street would have been comparable to figure 3. The trees in the left foreground are umbrella trees. Merced, Calif.; midsummer.

Where trees are already on a street, the problem of planning for the future is frequently much complicated, especially if there are several kinds in good condition. Where there is but one good kind, gaps can be replanted with young trees of that sort. If there are poor trees of a good variety or trees of a poor or short-lived variety it would be advisable to remove these and do all the replanting at one time, so as to have the trees on the street as nearly uniform as possible. Where there are several good varieties in good condition the sensible thing is to care for the trees that are there and then, after careful study, decide on one variety for all future plantings on that street.

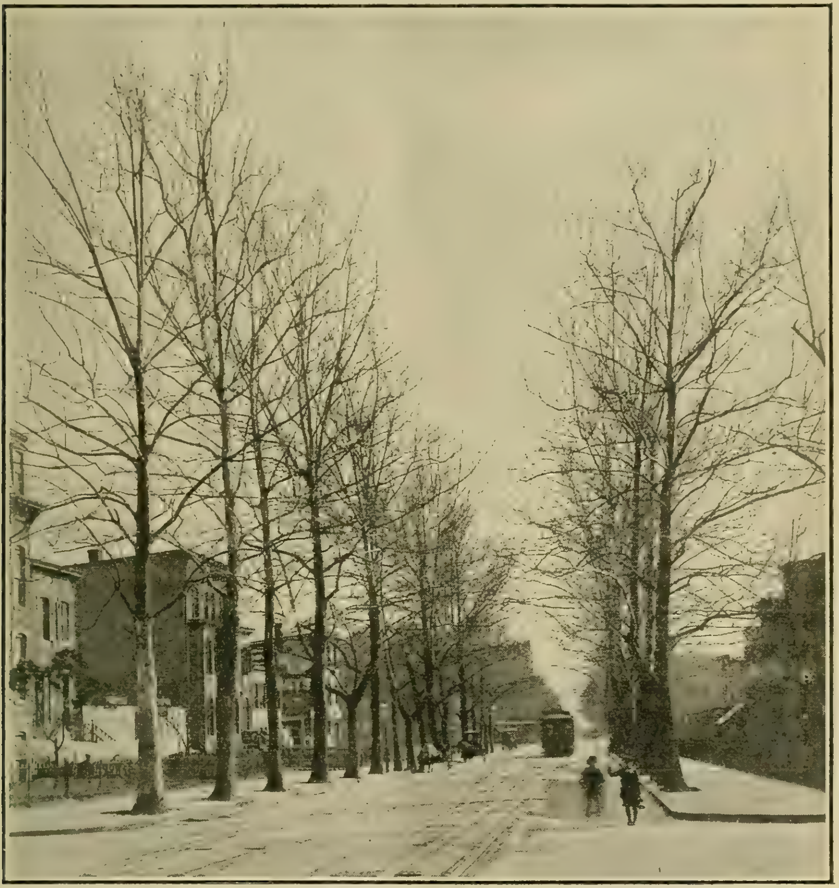
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FIG. 8.—Trees 20 feet apart that should be at least 60 feet apart. Sycamores in Washington, D. C., as they appear in late winter.

SPACING TREES.

A common fault in all street planting is to put the trees too near together. (Fig. 8.) This is more evident where the work has been done by the abutting property owners than by municipalities.

After trees are started and have attained some size it is extremely difficult to get them removed, even where the good of the remaining trees demands it. The removal of a fairly good tree merely because it is short lived in order to make room for a good one that will be permanent does not appeal to the average citizen. Where trees which have been planted by the property holder come under city control a strong feeling of proprietorship still remains, which is outraged by the suggestion of the removal of even poor trees. Where all the work is under city control good work is often hampered by a strong public sentiment against the removal of trees, even though they are poor or crowding.

Because of this difficulty it is extremely important that young trees be planted farther apart than at that time seems reasonable. If they are planted as far apart as is proper for mature trees the distance will be so great as to make planting seem a joke. If they are planted half the distance apart they should be when mature, good results would follow if the intermediate trees were removed when they nearly touch those to be left. As the intermediate trees would probably not be removed, or not until too late for the good of the remaining ones, planting had better be sufficiently far apart in the beginning to avoid the necessity of later removals. In the beginning the trees will be too far apart and when mature too close together, but it seems to be the alternative imposed by a misguided public opinion.

There is scarcely a community that would permit the removal of interplanted trees from a street of fine elms, oaks, or other worthy varieties without a protest that would be the almost sure political death of the administrative authorities responsible, no matter how great the need or how much expert support they might have. If short-lived intermediate trees were used they would not be likely to be taken out before they died, and they probably would not die before they had irreparably injured the permanent trees. The removal of surplus or interplanted trees can be made with least shock to the community by gradually narrowing the tree tops by severe pruning from year to year on the sides next the permanent trees until finally they are so narrow they may be removed and leave only small openings between the permanent trees. Even this method will not materially lessen the public protest at the final removal.

A common practice is to set street trees 35 feet apart. If it were practicable to remove one-half the trees at the proper time this would be a good distance, but in the eastern half of the United States and on the Pacific slope 50 feet apart is close enough for most varieties, and for the larger growing trees 60 to 70 feet would be better.

CONDITIONS FOR TREE GROWTH.

In order to grow, trees must have a soil of suitable texture, in proper mechanical condition, that contains sufficient available mineral elements and plenty of organic matter, and, last but not least, a constant supply of moisture and air. In addition to these there must be in active growth in the soil many forms of organic life that are in various ways preparing the material in the soil for the use of the larger plants. Not only must these things be present, but others that are deleterious must be absent, whether the substance is hurtful in itself or whether it is an excess of one that is otherwise beneficial.

Above the soil three things must be present—air, sunlight, and moisture—and, as in the soil, harmful things must be absent in order to have success. Among the deleterious substances are sulphur and other fumes and soot and other products from incomplete combustion.

Some of the more obvious things with which a city tree has to contend are: Water-tight pavements, both on the sidewalk and street, that prevent the admission of air and water; the removal of the topsoil in street grading, thus forcing the tree to exist on the good soil provided in the hole; careless digging near the tree for gas, water, and electric service, and especially for the placing of curbstones; the saturation of the soil with illuminating or sewer gas from defective pipes (fig. 9); the pouring of salt water from ice-cream freezers into gutters, where it may find its way into the soil near tree roots; the gnawing of the trunks by horses; and the cutting of the tops by linemen and tree trimmers.

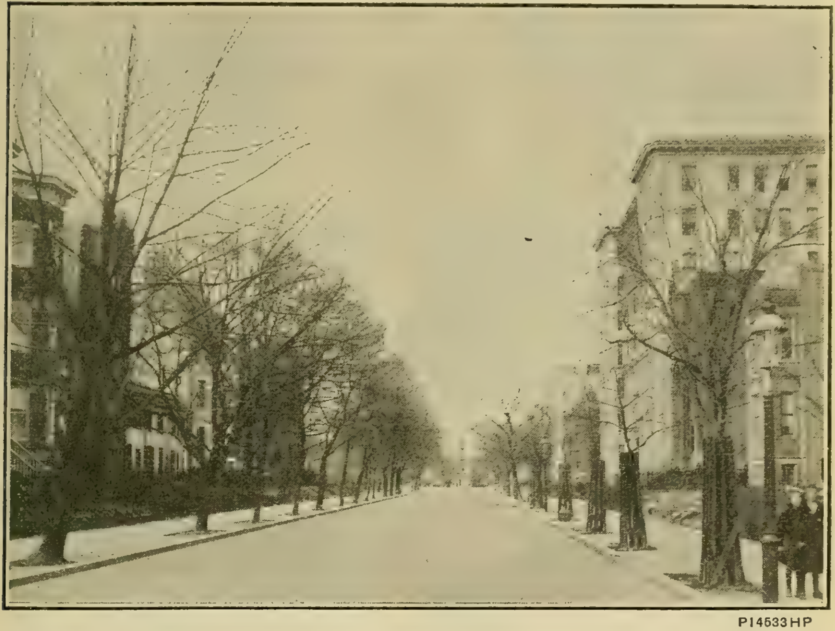
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FIG. 9.—The irregularity in the size of the trees shown is due to a part of the first planting having been killed by illuminating gas from defective pipes. Norway maples as seen in Washington, D. C., in late winter.

Because of the uncongenial conditions for the growth of trees on city streets comparatively few kinds are satisfactory for such use.

Among those available are some that will grow under extremely trying conditions. Kinds can be found that will thrive wherever it is suitable for human beings to live. If it is impossible to grow trees on a street, as a health measure that street should be closed for human use until conditions are so improved that it will support trees.

More kinds will thrive under suburban conditions where only a small portion of the roadway is covered by an impervious coating, where the parking spaces are liberal, and where the street is lined with open lawns than under the conditions in a city, where the street is covered with a water and air proof coating and the sidewalks with an impervious material, where parking spaces are limited, and where adjoining lawn areas are small or lacking. By a careful selection of kinds, all conditions in a city can be met. In some places bad conditions could have been improved greatly by a little forethought; in others, such conditions can be bettered. These details, like many other matters connected with city planning, have been ignored, but should be considered immediately, especially by villages and small cities. Figure 6 shows how an opportunity for creating a beauty spot has been lost sight of, while figure 10 shows how a city has utilized less ground to increase the comfort and attractiveness of its business center.

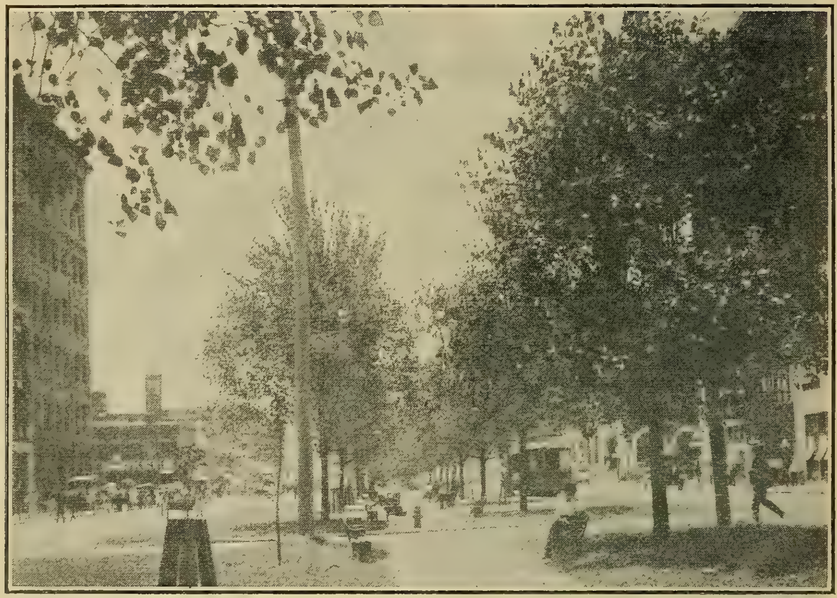
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FIG. 10.—A business center relieved by a parking with Carolina poplars. Macon, Ga.; late summer.

A common mistake in ambitious young cities and many old ones is to pave more of the width of the street for traffic purposes than is likely ever to be needed. By reducing the roadway and throwing the remainder into liberal parking spaces much is added to the attractiveness and comfort of a city. A contrast in the two methods of treatment is illustrated in figures 11 and 12. The recommendation that the roadway prepared for travel be made narrow is not to be interpreted as a reason for lessening the area dedicated to the public use; in fact, in most cities, especially in the northeastern quarter of the United States, too little space has been reserved from houseline to houseline (fig. 13). By reserving more room between the houses and

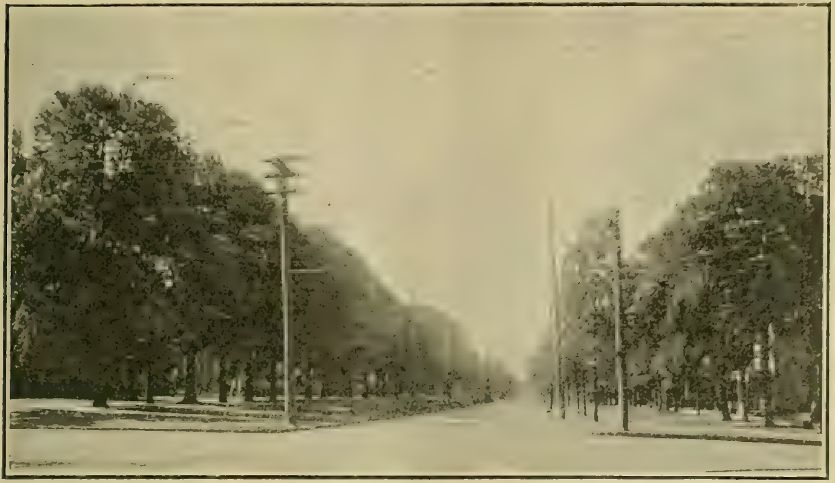
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FIG. 11.—A street well proportioned in width of roadway, sidewalk, and parkings, with willow oaks on the left, American elms on the right, and young Carolina poplars near the roadway that should be removed. Columbus, Ga.; midsummer.

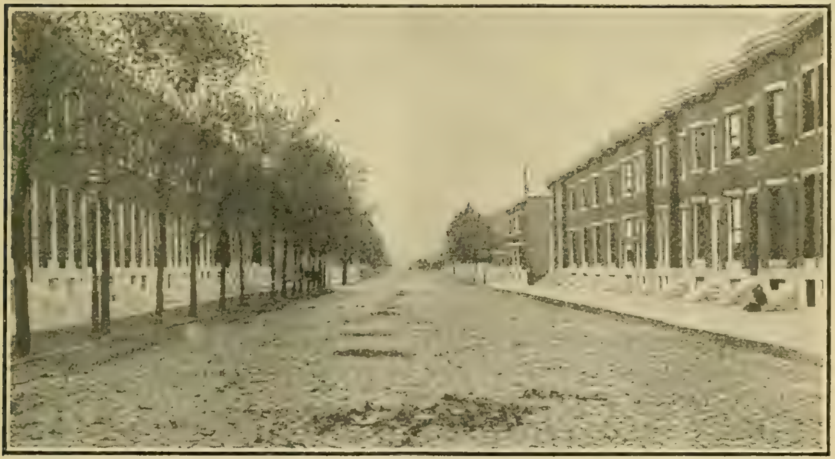
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FIG. 12.—A street with too much pavement and too little parking space. Carolina poplars in Baltimore, Md., in midautumn.

the street for use as lawns and gardens the conditions would be made more livable, opportunity would be offered for widening the public way without prohibitive expense if traffic or business demanded it, and the growing of street trees would cease to be a serious problem.

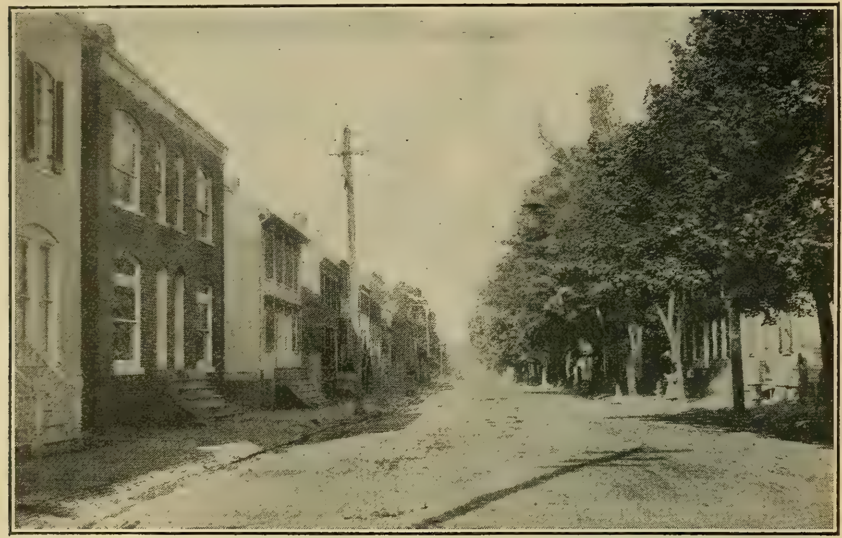
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FIG. 13.—A street with too little room from houseline to houseline. Note the more attractive appearance of the side with trees. Norway and silver maples in Frederick, Md., in midsummer.

KINDS OF TREES SUITABLE FOR CITY STREETS.

QUALITIES NECESSARY.

Compared with the whole number of trees used for ornamental planting, the number of kinds suitable for street planting is very small. For use under city conditions a tree must be adapted to the climate and to the soil upon which it is to be grown. It must have healthy foliage that withstands dust and smoke and a root system not easily affected by unusual soil conditions, by restricted feeding areas, or by root pruning when street improvements are made. The top should be in proportion to the width of the street upon which it is used, and it should be rather high headed or easily trained to that form and of open growth without being too spreading or sprawling.

Of minor consideration is the character of the foliage masses, whether dark or light, heavy and somber or open and airy, and also whether they have vivid autumn colorings. Only in the most southern parts of the country and in western California should evergreen trees be considered for street planting, and then only the broad-leaved evergreens, such as magnolias and live oaks. In the North the lack of sunshine during the short cloudy days of winter makes it desirable to admit all the light possible. Even in the South the question of sunshine should be considered when selecting varieties.

Narrow streets should be planted with columnar trees (fig. 14) or sometimes with small trees. Broad streets may be planted with spreading trees (figs. 3 and 16), or, if provided with a central parking space, with moderate-sized trees in the center and on the sides, or with trees on the sides suited to the space and formal trees in the center. (Fig. 15.)

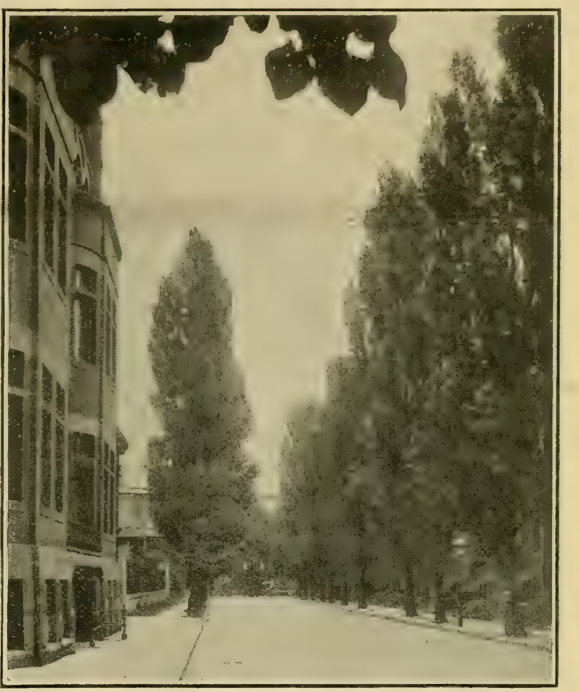

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FIG. 14.—Narrow upright trees (Lombardy poplars) on a narrow street. Washington, D. C.; midsummer.

As a rule, trees native to the locality that have been successfully grown in other cities should be given the preference. When a choice must be made between untried native trees and those tested in a city or town under different soil or climatic conditions, it is better to give the native trees the first trial. There are many native trees that are promising which have not been planted on a sufficient scale or under sufficiently varied conditions to demonstrate their real value for street planting over any considerable area. Many of the trees mentioned in this bulletin may prove valuable far beyond the areas for which they are suggested. The burr oak, the swamp white oak, the scarlet oak, the chestnut oak, the white oak, the sour gum, and others may be found on further trial to be as

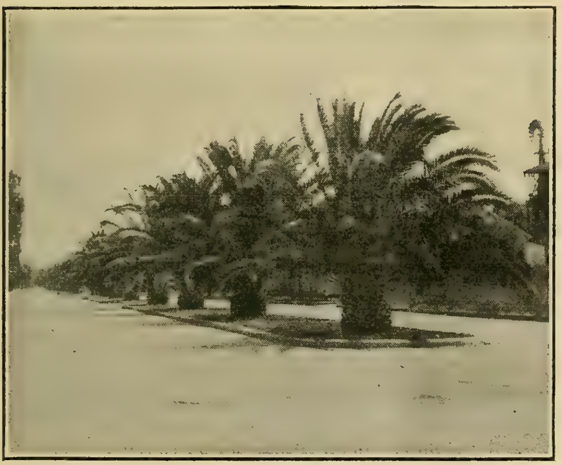

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FIG. 15.—Formal trees in a central parking, but appropriate trees wanting on the sides of the street. Canary Island date palms in Merced, Calif.; midsummer.

valuable as those already demonstrated to be valuable over large areas. Those mentioned have all been tested in a small way.

Caution should be used in selecting trees with conspicuous flowers and those with edible fruits or nuts, as in many parts of the country such trees are badly mutilated by the public. Even horse-chestnuts, although the nuts are not edible, are often broken by boys clubbing the trees. That public opinion can prevent such vandalism is in evidence all along the Pacific coast and at a few places in the East. Every effort should be made to create a sentiment that will protect these attractive additions to street adornment, but where the sentiment does not exist it is better to avoid the planting of such trees except in a limited way.

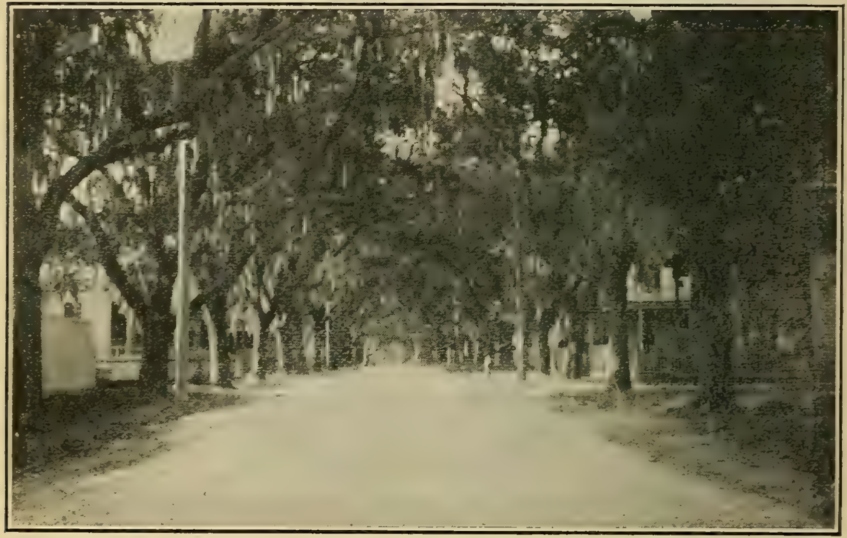

FIG. 16.—Live oaks, the handsomest southern street tree for broad streets. Biloxi, Miss.; late summer.

Besides the native trees there are many introduced trees that have proved valuable and many more that are worthy of trial.[1] A fair trial of promising introduced trees should be made, and the native kinds should be thoroughly tested.

TREES FOR DIFFERENT REGIONS.

To simplify the discussion of kinds of street trees likely to prove satisfactory, the United States has been arbitrarily divided into the regions shown in figure 17. An endeavor has been made to make each division cover an area having similar growing conditions, so that the trees suggested will be likely to thrive in all its parts. A discussion of the strong and weak points of the different kinds will be found with the description of the kinds farther on in this bulletin.

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[1] As examples of this are a number of new elms such as *Ulmus pumila* and *Ulmus densa*, besides lindens, poplars, and *Koelreuteria paniculata*, while *Pistacia chinensis* is suitable for warm regions. The Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture will be glad at any time to suggest new trees that are promising for any region.

Region 1.—Region 1 comprises the mild humid portion of the northern Pacific coast east to the Cascade Mountains, including the western third of Washington and Oregon and a portion of northern California. The trees native to western Europe are adapted to this region, as the climatic conditions are quite comparable. Most of our American trees also succeed here.

Some of the desirable varieties for street planting in region 1 are the Oregon, Norway, sycamore, and sugar maples; California walnut; tulip; European linden; basswood; sycamore; London plane;. white and European ashes; English and American elms; English, red, and pin oaks; ginkgo; and the black locust.

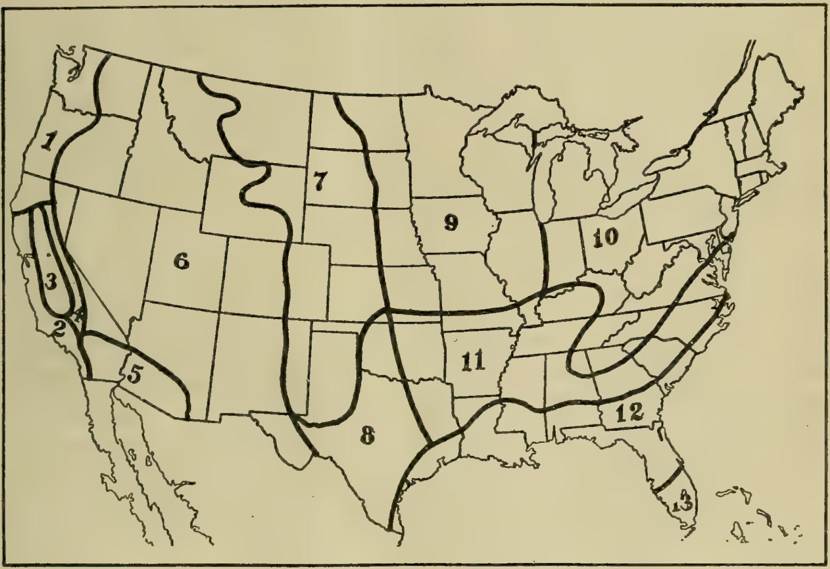

FIG. 17.—Outline map of the United States, showing the regions within which essentially similar conditions for tree growth exist.

Region 2.—Region 2 is that portion of California lying between the Sacramento and San Joaquin Valleys and the Pacific Ocean. Many varieties of trees will succeed here if given water. Because of the lack of water, unless specially irrigated the more drought-resistant species should be used.

Among the deciduous trees useful for this region are the London plane; the California and common sycamore; English, Huntingdon, and American elms; Oregon, Norway, sycamore, and English maples; white, green, and European ashes; red, English, and pin oaks; European linden; basswood; California walnut; honey and black locusts; horse-chestnut; Albizzia; and the Japanese varnish tree, or Sterculia.

Evergreen trees which will probably be successful in region 2 are the Eucalyptus[1] in variety, acacias, rubber, magnolia, California live oak, Victorian and poplar-leaved bottle trees, and in the southern portions the California pepper, silk oak, and jacaranda. Palms are much planted, but they do not make good street trees except where a formal effect instead of shade is desired.

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[1] Some cities have ordinances against the planting of certain trees because their roots sometimes obstruct sewers. Among these trees are the Eucalyptus in California and some of the poplars in several of the States.

Region 3.—Region 3 comprises the Sacramento and San Joaquin Valleys.

The deciduous trees for this region are the California walnut; London plane; California and common sycamores; Oregon, Norway, and sycamore maples; white, European, and green ashes; red, English, valley, and pin oaks; European linden; basswood; English and Huntingdon elms; honey locust; and horse-chestnut. Chinaberries and Texas umbrellas are much planted in these valleys, but are not good street trees. Olives and palms are suitable only for formal effects, while eucalypti are satisfactory but are liable to make trouble with defective sewers. Acacias grow especially well in this region except in the extreme north.

Region 4.—Region 4 includes the country from the Sacramento and San Joaquin Valleys to the crest of the Sierra Nevada Mountains. It varies in elevation and correspondingly in temperature and the amount of available moisture.

Where there is sufficient moisture, the deciduous trees recommended for region 3, except the valley oak and possibly the California sycamore, may be used. Where there is less moisture the thornless honey locust, black locust, green ash, hackberry, poplars, ash-leaved maple, and the American elm if it can be watered the first few years may be planted. In the warmer sections the chinaberry and Texas umbrella may be used.

Region 5.—Region 5 comprises the hot semiarid country of southern California and southwestern Arizona which is dependent on irrigation.

The best deciduous trees for this region are those suggested for the drier portions of region 4. With ample irrigation the deciduous trees recommended for region 3 might grow.

Among the evergreens the Texas palmetto, Parkinsonia, and the Washingtonia and some other palms can be used where other trees do not succeed. The red and desert gums may be used also in the drier regions. With ample irrigation the evergreens suggested for region 2 should succeed.

Region 6.—Region 6 comprises the intermountain section and extends from the crest of the Cascade and Sierra Nevada Mountains eastward to the eastern base of the Rocky Mountains. The region includes great variations in growing conditions, often in very short distances. As a whole it is semiarid, and in most places trees can hardly be expected to thrive without more or less irrigation, although in some of the mountain valleys and on some of the mountain slopes almost ideal conditions for tree growth exist.

In the drier parts of the region only those deciduous trees that are weeds under more congenial conditions can be grown. Those that can be planted with the greatest hope of success are the thornless honey locust, black locust, green ash, hackberry, and where the others do not succeed, the poplars and ash-leaved maple. If it can be watered for a few years the American elm usually can be grown, and in the southern half of the region the Mississippi hackberry will probably succeed. Near the southern border, on lower elevations, the chinaberry and Texas umbrella can also be planted. In the locations most favored naturally or where irrigation is possible, the trees suggested for region 9 can be used.

Evergreens that may be used for the drier portions of the southern part of region 6 are the Parkinsonia and the Texas palmetto.

Native trees may be found that will prove of greater value for limited areas than any suggested. Cities and towns contemplating street tree planting would do well to consult the nearest State agricultural experiment station or the United States Department of Agriculture if it is thought possible that something better has been found than the trees suggested.

Region 7.—Region 7 is the northern part of the Great Plains area from the foot of the Rocky Mountains at about the 5,000-foot contour line east to the ninety-eighth meridian. It is rather uniform in general conditions, the character of soil having no wide divergence and the elevation increasing gradually from south to north and east to west.

The rainfall gradually increases from west to east until at about the ninety-eighth meridian the conditions are more favorable for tree growth.

The trees to be relied on are the thornless honey locust, common hackberry, black locust, green ash, ash-leaved maple, the poplars, the Chinese elm, and the American elm if it can be watered the first few years after transplanting. The mossy-cup oak is another tree worth testing in a small way, as it is native a little east of the ninety-eighth meridian. The basswood and Norway maple would probably succeed if supplied with plenty of water.

Region 8.—Region 8 is the southern part of the Great Plains.

In addition to the deciduous trees recommended for the northern Great Plains (region 7) the Mississippi hackberry, Texas umbrella, and chinaberry may be successfully grown.

Evergreen trees that may be used in region 8 are the Texas palmetto and Parkinsonia.

Region 9.—Region 9 is the upper Mississippi Valley, including the area from that already considered to Lake Michigan and south to southern Kansas. It is more favorable to tree growth than regions 6 and 7.

Trees which will succeed here are the American elm; red, pin, mossy-cup, and other native oaks; white ash; sycamore; basswood; and Norway and sugar maples.

Region 10.—Region 10 includes the northeastern part of the country from eastern Illinois to the Atlantic Ocean, and extends southward through the Appalachian Mountains. It is most favorable for tree growth.

The best trees for street planting in region 10 are the red and pin oaks, London plane, sycamore, the staminate form of the ginkgo, basswood, tulip, Norway maple, white ash, thornless honey locust, American elm, and in the southern portion of the region on light land the sweet gum. The red and sugar maples are among the best trees for suburban conditions. The hackberry will grow, but should be discarded in favor of better varieties. The mossy-cup and chestnut oaks are worthy of trial on gravelly soils in the suburbs.

Region 11.—Region 11 includes the lower Mississippi Valley and the country east of the southern Appalachian Mountains, extending from the light lands near the South Atlantic and Gulf coasts to the northern limits of the distinctively southern flora.

The typical street trees of this region are the willow oaks (fig. 1) and water oaks, the former a valuable street tree, the latter good when young but comparatively short lived, with no advantages over the willow oak. Other good trees are the red, Spanish, laurel, Darlington, and pin oaks, tulip, sweet gum, American elm, red and Norway maples, and the ginkgo.

Region 12.—Region 12 is the land near the coast from Wilmington, N. C., to the Mexican border, exclusive of the southern part of Florida.

Good deciduous trees for this region are the willow, laurel, Darlington, and Spanish oaks, tulip, sweet gum, sycamore, London plane, American elm, and the staminate form of the ginkgo. The honey locust, red or scarlet maple, Norway maple, and the hackberries are not so good.

The live oak is the characteristic tree of region 12 (fig. 16) and is the pride of the cities that have used it. Even though an evergreen, it is an excellent street tree, as it is large, spreading, and open. The palmetto and palms thrive and may be used for producing formal effects. The evergreen magnolia is a good broad-leaved evergreen.

Region 13.—Region 13 consists of the southern part of Florida. The deciduous trees suitable for this section are the willow, Spanish, and southern red oaks; American elm; Mississippi hackberry; and in the southern half of the region the Poinciana.

Evergreen trees are better suited to region 13 than to any other portion of the United States except possibly southern California. Among the best are the live and laurel oaks, evergreen magnolia, camphor, rubber, silk oak, or grevillea, and casuarina. Eucalypti are planted to some extent in Florida, but the climate is such that only on the drier grounds of the interior are they likely to succeed, and even there they are not to be compared with other excellent species of trees that may be cultivated successfully.

TREES FOR SPECIAL PURPOSES.

In the heart of a city, where the greatest difficulty is experienced in getting trees to grow, the ailanthus will probably thrive when nearly all other kinds fail. The sycamore and the London plane are also good for such places. The Carolina poplar will frequently grow under these conditions, and its use may sometimes be warranted.

For very narrow streets the Lombardy poplar is the best tree. (Fig. 14.) Trees suitable for use within the reach of ocean spray or on sandy lands near the coast are the red oak and the red or scarlet maple south to Charleston, S. C., while the sweet gum and the live oak are equally good from Norfolk southward and along the Gulf of Mexico. The red oak, sweet gum, red maple, and eastern live oak are all grown successfully along the Pacific Ocean, while the California live oak can be used from San Francisco southward. The trees that endure the most alkali appear to be the bladder-nut tree,[1] London plane, peppermint gum,[2] blue gum,[3] the Washingtonia and other hardy fan palms, Canary Island date palm, the camphor tree, and *Acacia cyclops* and *Acacia retinodes*. Only the first two withstand severe freezing weather. The red oak and the red maple are worth testing for these conditions.

DESCRIPTIONS OF STREET TREES.

ACACIA.

The acacias, or wattles, are a large group mostly of small trees with showy yellow flowers. Although much used in California, many of them are too small to make satisfactory shade trees, and because of shallow rooting they are injurious to sidewalks. They also stump-sprout badly. They thrive in regions 2 and 3 and in restricted portions of regions 1 and 5.

The Australian blackwood,[4] blackwood acacia, or wattle, is a strong, upright tree, growing to a height of 75 feet and forming a well-shaped head. It is badly affected by citrus scale, and on this account its planting is sometimes prohibited.

The black wattle[5] is a strong-growing round-headed tree that reaches a height of 40 feet and has dark-green leaves.

The green wattle[6] is a rapid-growing tree, reaching a height of 60 feet and forming a round head with finely cut leaves.

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[1] *Koelreuteria paniculata.*

[2] *Eucalyptus amygdalina* Labill.

[3] *Eucalyptus amygdalina angustifolia.*

[4] *Acacia melanoxylon* R. Br.

[5] *Acacia decurrens mollis* Lindl.

[6] *Acacia decurrens* Willd.

The silver wattle[1] is much like the black wattle except that its leaves and young branches are covered with a whitish down.

AILANTHUS.

The ailanthus,[2] or tree of heaven, is a tall, broad, handsome tree that is especially valuable in the heart of closely built or smoky cities. The staminate and pistillate flowers are borne on separate trees. Only the pistillate trees should be used, as the odor of the blossoms of the staminate ones is very objectionable for about 10 days in late spring. These may be produced by grafting from pistillate trees or by propagating from suckers or root cuttings from such trees if they have not been grafted. The ailanthus may not succeed in regions 5 and 13.

ASH.

There are three kinds of ash trees that are useful for street planting.

The white ash[3] is a large oval-headed tree, reasonably satisfactory on rich lands in regions 1, 2, 3, 4, 9, 10, 11, and 12, but it is better adapted to suburban than urban conditions.

The green ash[4] is one of the few successful trees in regions 6, 7, and 8 and may succeed in region 5. It grows well throughout the remainder of the United States, but is of less value than other trees there. It is much smaller than the white ash, with a broad round top.

The European ash[5] is a large, handsome, round-headed tree suited to regions 1, 2, 3, and 4.

CAMPHOR.

The camphor tree[6] is a large, handsome, oval-headed evergreen that will succeed in the southern half of region 2, in regions 3, 5, and 13, and in the warmer parts of region 12. It will endure more frost than the orange, and where it is successfully grown it is deservedly popular.

CHINABERRY.

The chinaberry,[7] sometimes known as the China tree, is a small, round-headed, short-lived tree that will grow in regions 2, 3, 5, 8, 11, 12, and 13 and near the southern edge of region 6. It is too short lived to be considered for planting where other trees will grow

The umbrella tree,[8] or Texas umbrella, is a small, compact form of the chinaberry with an umbrella-shaped top. It is useful for formal effects, as in the parking on a wide street where taller trees are used on the side. It will grow in regions 2, 3, 5, 8, 11, 12, and 13 and in the southern parts of region 6.

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[1] *Acacia decurrens dealbata* F. Muell.

[2] *Ailanthus altissima* (Mill.) Swingle (*A. glandulosa* Desf.).

[3] *Fraxinus americana* L.

[4] *Fraxinus lanceolata* Borck.

[5] *Fraxinus excelsior* L.

[6] *Cinnamomum camphora* (L.) Nees and Eberm.

[7] *Melia azedarach* L.

[8] *Melia azedarach umbraculiformis* Berckmans and Bailey.

ELM.

The elms are large, handsome shade trees suitable for use over a wide range of territory.

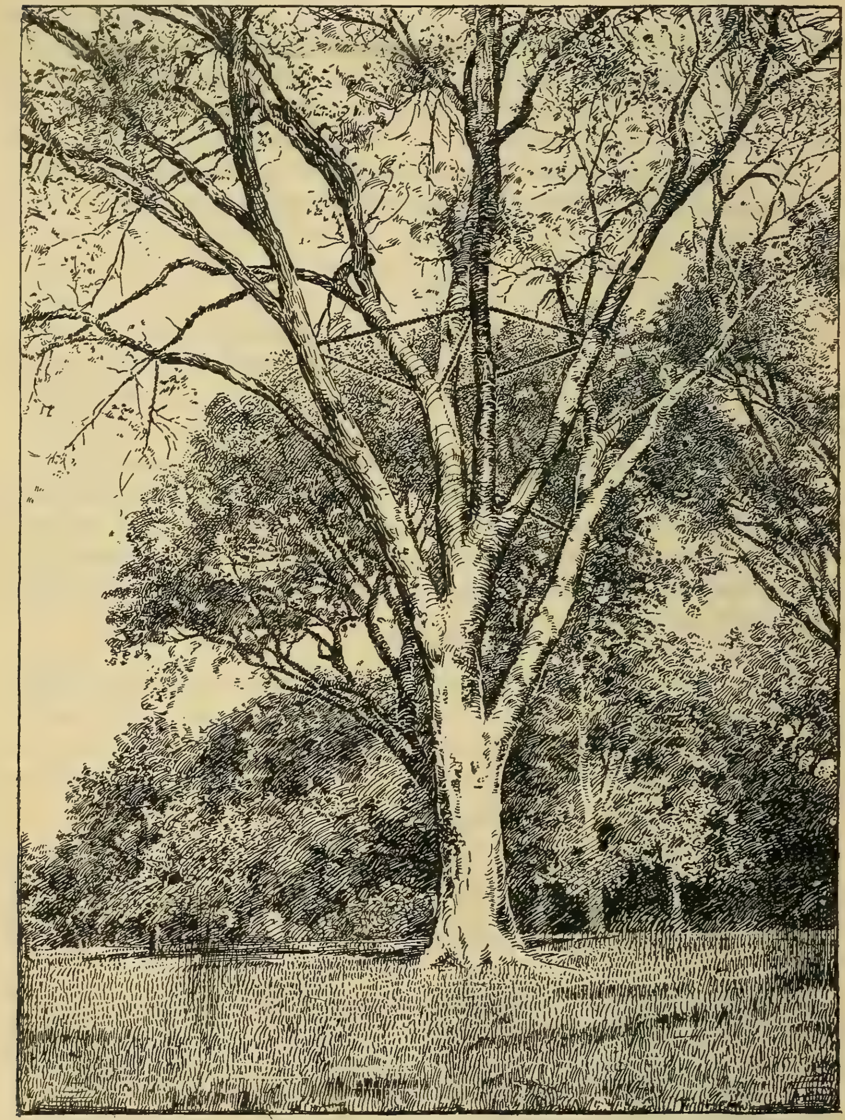

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FIG. 18.—An American elm with crotches liable to be split by heavy winds. Note the supporting chains.

The American elm,[1] sometimes called the white elm and water elm, is one of the handsomest American shade trees. (Fig. 3.) It has been the standard street tree of New England, giving to the roadsides and village streets the characteristic appearance which is so attractive to summer visitors.

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[1] *Ulmus americana* L

The American elm is tall and spreading, and where planted as near together as is customary on streets and country roads the effect of the mature trees is that of an arch formed by the growing together of their spreading tops. It is of rapid growth and long lived.

This elm drops its leaves very early in the fall, but it comes into leaf early in the spring. Because of its manner of branching it is especially liable to be split by heavy winds. This trouble may be lessened by selecting and planting specimens with a close, compact habit of growth or possibly also by great care in training young trees. Two limbs separating from one another by a very small angle, that is, when they start to grow in nearly the same direction, make a crotch that is liable to split. (Fig. 18.) Where two limbs separate at nearly a right angle or where three or more limbs of about equal size grow from a common point or very nearly so, the crotch is likely to be much stronger. Careful pruning and training to provide a proper system of branches may be especially helpful with this elm.

Because of the attacks of the elm leaf-beetle[1] and the European elm bark louse,[2] many handsome trees have been severely damaged or killed before communities were properly equipped for fighting them, for with careful spraying these insects may be kept in check. However, on account of the existence of these pests and because they are gradually spreading to new territory, tree planters should consider carefully whether it is advisable to plant the elm in their localities. Where there is no danger from these insects, this elm is one of the best of street trees. Consultation with the nearest State agricultural experiment station or with the Entomologist of the United States Department of Agriculture would be advisable in order to determine this point.

The best specimens are to be found in the northern part of region 10, although the elm is being grown all over the United States and is proving a valuable street tree even in towns and villages of regions where the rainfall is as low as 15 inches. It is not recommended for planting in regions 3 and 5.

The English elm[3] is a tall, oval-headed, compact, handsome tree with leaves smaller than the American elm and which stay on much later in the fall. In regions 1 and 2 it is at its best, in the former equaling the American elm and in the latter excelling it. It also thrives in regions 3 and 10 and in the eastern part of region 11.

The Huntingdon elm[4] is a comparatively round-headed European variety.

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[1] *Galerucella luteola* Müll.

[2] *Gossyparia spuria* Mod. (Data regarding both insects furnished by the Bureau of Entomology.)

[3] *Ulmus campestris* L.

[4] *Ulmus hollandica vegeta* (Lindl.) Rehd.

It is a large, handsome tree with good foliage and is more compact in growth than the American elm. It succeeds well in regions 1, 2, 3, and 4.

The wahoo, or winged elm,[1] is native to the South Atlantic and Gulf States near the ocean. It has larger leaves than the American elm and is not as spreading in its growth, but it succeeds well on city streets in regions 11, 12, and 13.

EUCALYPTUS.

There are a large number of species of Eucalyptus, many of which can be used for street planting in regions 2, 3, and 5. Some cities prohibit their planting because their roots are liable to penetrate defective sewers, and in other cities they must be kept at least 70 feet from a sewer, though even this distance may not prove permanently effective.

The roots of any tree are liable to find their way into a defective sewer, but the trees mentioned are especially noticeable because of their vigorous root growth. It may be questioned whether a tree should be condemned for this growth, as it may be better to have a defective sewer thus revealed than to continue a menace to public health.

Eucalypti are also being planted in southern Florida, but on account of the moist climate there it is not to be expected that they will succeed as well as in the other regions mentioned. They are tall, handsome, quick-growing trees, usually bearing two kinds of leaves at some time in their development.

The blue gum[2] is one of the best eucalypti and the one most commonly used in California. It is tall, globular headed, handsome, and will survive several degrees of frost, but it will not withstand the heat of the deserts in region 5. Its roots are especially liable to invade sewers.

The desert gum[3] is one of the trees most resistant to heat and cold, and it makes a handsome avenue tree. It has pendent branches that have a tendency to severe splitting with age, but with early attention this may be overcome largely. It may prove especially valuable for region 5.

The manna gum[4] is another Eucalyptus which withstands several degrees of frost and makes an excellent roadside tree. Some forms shed their bark in long bands that leave the trunks almost white. Many people consider it a dirty tree on this account.

The red gum[5] grows with a broad head, is one of the most resistant of the eucalypti to frost, drought, and heat, and succeeds wherever any of these trees can be grown in regions 2, 3, or 5, but is most useful in region 5.

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[1] *Ulmus alata* Michx.

[2] *Eucalyptus globulus* Labill.

[3] *Eucalyptus rudis* Endl.

[4] *Eucalyptus viminalis* Labill.

[5] *Eucalyptus longirostris* F. Muell.

The sugar gum[1] is a drought-resistant variety, but it does not withstand cold. It is a common roadside tree in southern California, but becomes straggling with age.

GINKGO.

The ginkgo,[2] or maidenhair tree (fig. 4, *B*), is a native of Japan that thrives in a cool climate or a hot, moist one and succeeds in regions 1, 9, 10, 11, 12, and 13. It is extremely erratic in its behavior, sometimes growing well, sometimes practically not growing at all, but where it succeeds it is very disease resistant, and it withstands severe windstorms remarkably well. The leaf is peculiar in appearance, resembling in outline a much enlarged leaflet of maidenhair fern with a corrugated surface. The tree is conical when young, but as it reaches maturity its top usually fills out, making a broad, almost flat-topped, handsome tree. Only the staminate form should be used, because the pistillate form bears fruits the flesh of which is slippery and dangerous when it drops to the pavement, and to some people it is somewhat poisonous to the touch. Ginkgo trees, therefore, would need to be secured by budding or grafting from the mature staminate form.

HACKBERRIES.

The hackberry,[3] or sugarberry, is especially valuable in regions 6, 7, 8, and 9, as it grows satisfactorily where there is comparatively slight rainfall. It is also much used in region 11, but should be superseded there by other varieties that are better. It is of moderate size with an oblong head and of rather open growth. It is comparatively short lived. Its leaves are much like those of the elm.

The name sugarberry comes from the sweet black berries that are borne in the early fall. The tree is sometimes affected by a fungous trouble known as witches'-broom. This trouble causes large numbers of small sprouts to start from the affected portion, which gives the infected tree an unsightly appearance. The hackberry should not be planted where this trouble is prevalent.

The Mississippi hackberry[4] is a large, open, oblong-headed tree with smoother leaves than the common hackberry. It is useful in the southern part of region 6, in region 8, and to some extent in regions 11 and 12. It thrives well under the same adverse moisture conditions as the common hackberry. The trunk and the large branches have little wartlike projections of the bark scattered irregularly over them. The small twigs are sometimes more or less spotted or winged in the same way. The tree is rather larger than the common hackberry and apparently is less subject to witches'-broom.

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[1] *Eucalyptus corynocalyx* F. Muell.

[2] *Ginkgo biloba* L.

[3] *Celtis occidentalis* L.

[4] *Celtis mississippiensis* Bosc.

HONEY LOCUST.

The honey locust[1] is a large, open, round-headed, fine-foliaged tree, admitting much light through its top. (Fig. 19.) The common form has stiff spines 2 to 6 inches long, or even longer. There is also a form without spines, which is the one that should be used for street planting. It is a useful tree in regions 1, 2, 3, 9, 10, and 11, but is especially valuable for planting in regions 6, 7, and 8, and may prove useful in region 5.

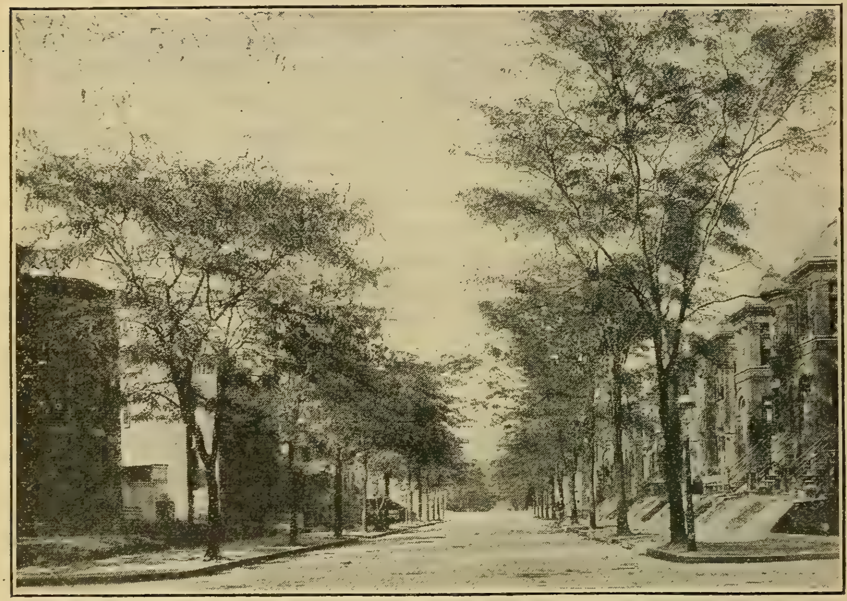

FIG. 19.—A street shaded with honey locusts, as seen in late summer. Washington, D. C.

HORSE-CHESTNUT.

The horse-chestnut[2] has handsome blossoms that are very showy, and when in bloom an avenue of these trees commands attention. It is a close relative of the buckeye, or Ohio buckeye, which is also a handsome tree, though less desirable. It is objectionable because it is likely to be broken by boys clubbing it for its nuts, which are inedible, or where its leaves are affected with a midsummer blight which makes it unsightly during the remainder of the season. It is a medium-sized round-headed tree that does much better under surburban than under city conditions. It thrives in regions 1, 2, 3, and 10.

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[1] *Gleditsia triacanthos* L.

[2] *Aesculus hippocastanum* L.

LINDEN.

The basswood,[1] or linden, is a large round-headed tree that is excellent for roadsides in surburban locations and does well on city streets if the conditions are not too severe. On account of the dark upper surface and the lighter under surface of the leaves and the sweet-scented blossoms in early summer it is much admired. It is not as reliable as some of the other shade trees, as when young it is sometimes attacked at the base of the trunk by a fungous growth that kills the tree. When once established it forms handsome avenues. It is suited to regions 1, 2, 3, 4, 7, 9, 10, and 11.

The linden,[2] or European linden, has much smaller leaves than the American linden, or basswood, with more contrast between their upper and lower surfaces. It is not much different in size, but is a little more compact in growth and holds its leaves longer in the fall. It is a useful tree for street planting in regions 1, 2, 3, 4, 9, 10, and 11.

LOCUST.

The locust,[3] or black locust, is one of the desirable street trees in regions 6, 7, 8, and probably in region 5, as it thrives with comparatively little moisture. It makes a moderate-sized oval head that bears sweet-scented white flowers in late spring or early summer. Its greatest drawback is its liability to serious injury and disfigurement by the locust borer,[4] but with proper care this injury can be prevented.[5] In some parts of the East it is also subject to a leaf miner[6] that gives its foliage a burned appearance. In region 3 it holds its seed pods for several years and thus becomes very unsightly.

MAGNOLIA.

The evergreen magnolia[7] is one of the few good evergreen trees for street planting, but it is adapted only to regions 1, 2, 3, 11, 12, and 13. There are but few conditions that warrant the planting of a tree having foliage as thick as this, because of the dense shade, which is especially undesirable in winter. It grows to be a large oval-headed tree and bears beautiful large white blossoms in late spring or early summer.

MAPLE.

Among the maples are some undesirable trees much used for street planting and some that are valuable only in restricted areas or under special conditions. The maples are not as satisfactory for street planting as usually has been supposed, few of the species being suitable for this purpose and these only in a limited way.

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[1] *Tilia americana* L.

[2] *Tilia platyphyllos* Scop.

[3] *Robinia pseudacacia* L.

[4] *Cylene robiniae* Forst. (Data furnished by the Bureau of Entomology).

[5] See U. S. Dept. of Agriculture Bulletin 787, entitled "Protection from the Locust Borer."

[6] *Chalepis dorsalis* Thunb.

[7] *Magnolia grandiflora* L.

The ash-leaved maple, or box elder,[1] is native to all of the country east of the Rocky Mountains except the regions near the South Atlantic and Gulf coasts. It is a small, quick-growing tree that will thrive almost anywhere, but it reaches maturity early. Because of its early decay and of its being subject to destruction by wind, it should not be used for street planting where other trees succeed. It would be a good tree for interplanting were it safe to risk taking out some of the trees at the right time. The objection to using these trees is that they would be so likely to look larger and better than the permanent trees at the time they should be removed that public opinion would probably resent their removal. There may be conditions requiring the use of this tree in regions 6, 7, and 8, but it should be grown only when the other trees suggested for these regions will not succeed.

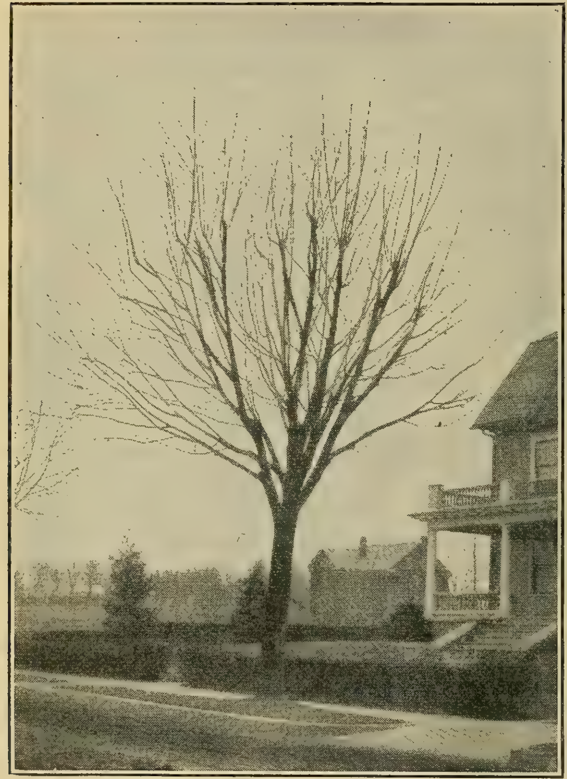
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FIG. 20.—A Norway maple, as seen in late winter, showing its poor shape when trimmed to a high head.

The English maple[2] is small, round headed, with small dark-green leaves, useful in regions 1, 2, 3, and 4.

The Norway maple[3] is round headed and eventually reaches large size, but, as compared with most of the other maples, it is slow growing (fig. 4, *C*). The persistence of its tendency to form a low head makes it difficult to give it a high head of desirable shape (fig. 20). It is also very thickly branched, and its foliage, being heavy and dark green, permits but little light to pass through. On this account it is rather undesirable for street planting. By severe pruning of the interior of the head this defect may be somewhat overcome. The tree is practically disease and insect free, with the exception of a liability to infestation by a leaf aphis[1] which produces yellow spots on the leaves and causes them to drop prematurely; also, the honeydew which they produce is so abundant at times as to cover the leaves and wet the sidewalk beneath the tree, the leaves under certain weather conditions becoming blackened with dust accumulating and a fungus growing in the secretion, thereby giving the tree an unsightly appearance. This aphis, however, is not always present and does not seriously injure the tree. The Norway maple comes into leaf later than most of the other maples, but holds its leaves later in the fall. They usually assume a bright yellow hue before they drop. The leaves are preceded by an abundance of yellow-green blossoms. On account of its dense shade and masses of fine fibrous roots it is difficult to grow grass under this tree. Its good shape and attractive dark-green foliage make it popular for street planting in spite of its dense, low head. It will succeed in regions 1, 2, 3, 4, 9, 10, 11, and 12.

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[1] *Acer negundo* L.

[2] *Acer campestre* L.

[3] *Acer platanoides* L.

The Oregon maple[2] is the large-leaved maple of the northern Pacific slope. It forms a large round head, and with its unusually large dark-green leaves makes a very attractive street tree that succeeds well in regions 1, 2, 3, and 4. It is valuable and worthy of more extended cultivation on the Pacific coast.

The red maple,[3] scarlet maple, or swamp maple is one of the most widely distributed of American trees. It is found from Canada to the Gulf of Mexico and west to the Rocky Mountains. Its leaves are the smallest of any of the eastern native maples, but it grows large and the trees are usually of rather upright outline. It is better adapted to suburban conditions than to city streets and is one of the few trees that succeed well near the ocean. It has bright-red blossoms before the leaves appear. The young leaves and fruits are also red. The mature leaves begin to color early, some branches coloring as early as the middle of July, assuming brilliant reds and yellows and staying on later than those of the sugar maple. It is a handsome tree that is not as much used as it deserves to be in regions 1, 9, 10, 11, 12, and 13.

The silver maple,[4] also called the soft maple, white maple, and swamp maple, is probably more used for street planting through the whole United States than any other tree, and with one exception it is the least desirable. It is usually planted because it is a quick-growing tree, but it is not more rapid in growth than several other much better trees. There are three serious objections to its use as a street tree. The first is its brittle wood, which at an early age is easily broken by ordinary windstorms and causes it when a comparatively young tree to become unsightly. The second is its shallow rooting, which has a tendency to destroy pavements and also makes it difficult to grow grass near the trees. The roots also will grow into sewers. The third is the tendency to decay; the tips of the limbs frequently die, leaving the whole top of the tree bare of leaves, and the wood decays quickly, especially if the bark is broken. For this reason it does not stand pruning as well as most other street trees, and it probably has been pruned more ruthlessly than any other tree, unless it is the Carolina poplar. It should never be severely deheaded or, as it is popularly called, "dehorned" (fig. 21), as the stubs will practically never heal over, and from these cuts decay will start, which in a very few years will rot the center of the limbs and trunk and thus destroy the tree. Although it forms a large round head with an open top and its foliage is pale green above and almost white beneath, making a very delightful shade, on account of its weaknesses it should never be used for street planting where other trees can be made to grow.

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[1] *Periphyllus lyropictus* Kess. (Data furnished by the Bureau of Entomology.)

[2] *Acer macrophyllum* Pursh.

[3] *Acer rubrum* L.

[4] *Acer saccharinum* L.

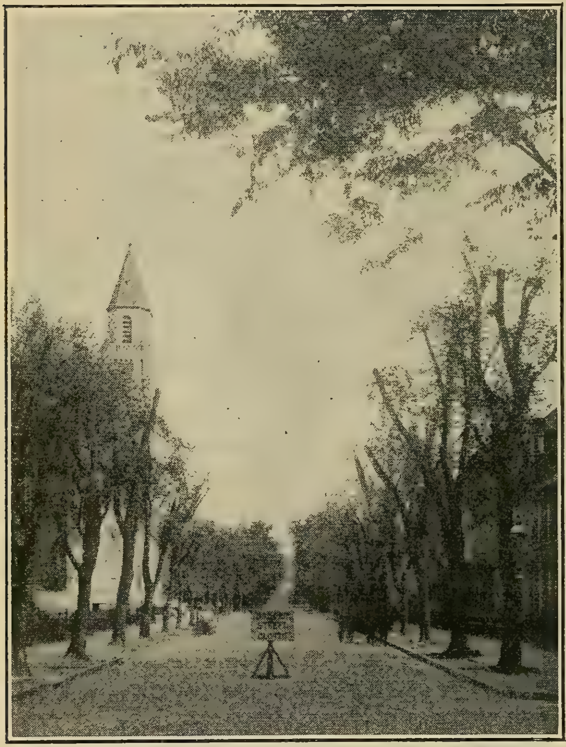
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FIG. 21.—Silver maples severely headed back, an improper way to treat trees, especially silver maples, except under very unusual conditions. Washington, D. C.; midsummer.

The sugar maple,[1] or hard maple, is especially adapted to gravelly soils in regions 1, 10, and 11, the northern parts of regions 2 and 3, and the eastern and southern parts of region 9. It is oval headed, large, and handsome, having red blossoms which individually are inconspicuous but which in mass are showy early in the spring before the leaves appear. The leaves come early, but in late summer they begin to turn brilliant yellow and red and drop before most other leaves. The sugar maple does not thrive under city conditions, but is admirably adapted to suburban conditions.

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[1] *Acer saccharum* Marsh.

Although the sycamore maple[1] is similar in appearance to the Norway maple, it is not a satisfactory street tree in the eastern United States. It succeeds, however, in regions 1, 2, 3, and 4.

OAK.

Of the trees used for street planting the oaks are best. They probably have not been more widely planted because of the prevalent belief that they are slow growers and because in the North they are rather difficult to transplant. Although some of the handsomest species, like the white oak and live oak, are slow growers, those suitable for street planting are comparatively rapid growing. The white oak and sugar maple shown in figure 22 are each 32 years old and although differing in shape are practically the same size, yet the sugar maple is considered a sufficiently rapid growing tree to be planted frequently as a street tree, while the white oak is seldom so used. The oaks are hardy, most of them are long lived, and for the most part they are free from disease and insect attacks. Some of the southern species are subject to attacks of mistletoe.

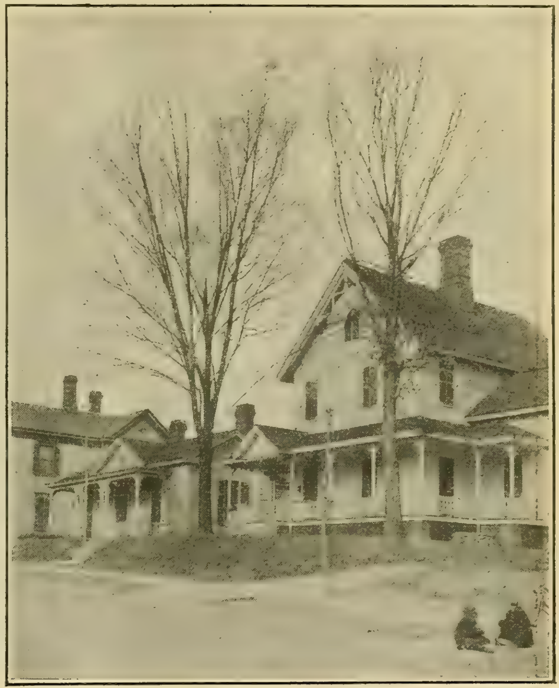
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FIG. 22.—A sugar maple (on the left) and a white oak (on the right), each 32 years old and nearly the same size.

The California live oak[2] is an evergreen suitable for use in region 2 and succeeds adjacent to the ocean. It is also useful in region 3 and in the western part of region 5. It is easily transplanted if handled young, and especially so when planted from pots.

The chestnut oak[3] is a native of gravelly soils on eastern mountains and is suitable for gravelly soils in suburban locations in regions 9, 10, and 11. It is a large, handsome tree.

The Darlington oak[4] is a form of laurel oak especially desirable for street planting. It is large, round headed; the leaves are a trifle smaller and not quite so nearly evergreen as the laurel oak. It is found wild about Darlington, S. C., where a good form of the laurel oak appears to have been introduced as a shade tree in the early part of the nineteenth century. (Fig. 23.) Its range of usefulness lies in regions 11 and 12.

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[1] *Acer pseudoplatanus* L.

[2] *Quercus agrifolia* Nee.

[3] *Quercus montana* Willd. (formerly *Q. prinus*).

[4] *Quercus laurifolia* Michx.

The laurel oak[1] is a large, oval-headed tree that is not as rugged and irregular as the live oak, but is suitable for street planting in regions 11, 12, and 13. It has large, thick, glossy leaves, and in the warmer regions it is almost evergreen. It is readily transplanted, but as it is not so common in the woods as the willow oak and the water oak, it has not been so much used as a street tree.

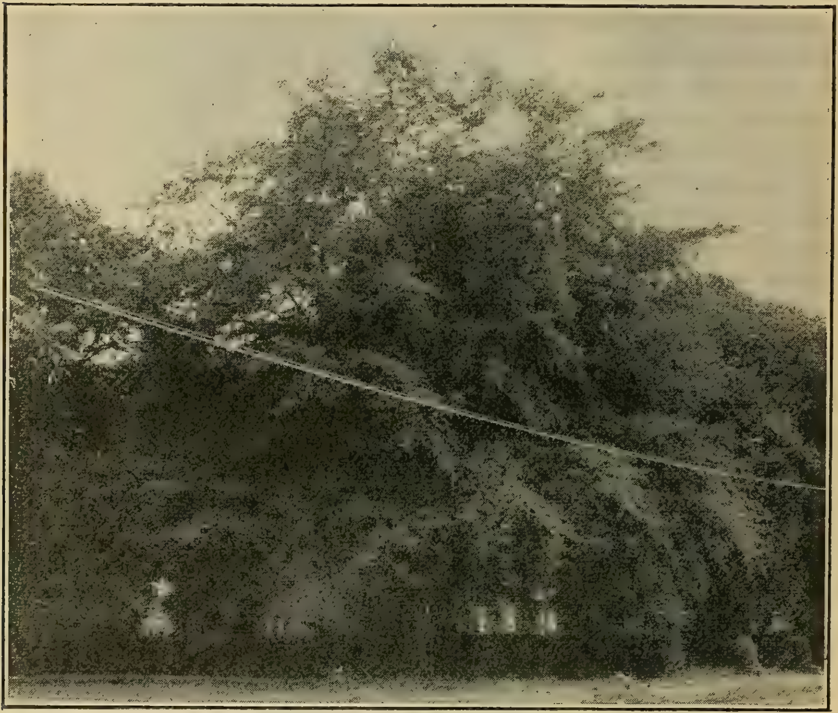

FIG. 23.—A Darlington oak as seen in late summer, Darlington, S. C.

The live oak[2] (fig. 16) is probably the noblest and most majestic of the oaks of regions 12 and 13. It is evergreen and of slow growth, but wherever it is found, whether on streets or in public parks, it is the pride of the people. Although an evergreen it is sufficiently open headed to make a good street tree. When it becomes old it is spreading and as a rule does not form as high a head as the willow oak and the laurel oak. Compared with other southern oaks it is difficult to transplant. It is of sufficient merit to be used on broad streets, and especially on boulevards, where the good of the future as well as the present is considered.

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[1] *Quercus laurifolia* Michx.

[2] *Quercus virginiana* Mill.

The burr oak,[1] or mossy-cup oak, is native in the northeastern United States and west of the Mississippi River on the hills lying between the river bottoms and the prairies west to the western parts of the Dakotas and Nebraska and central Kansas and Texas. It is a large, handsome tree that should prove satisfactory under suburban conditions in regions 7, 8, 9, 10, and 11 and on fertile well-watered soils.

The pin oak,[2] sometimes called the swamp oak, is a tall tree, conical when young, oval at maturity, with a drooping habit of the lower branches. The leaves are quite finely divided and are of a bright glossy green. The tree comes into leaf late in the spring and holds its foliage late in the fall. One objection to the pin oak for street planting is that on many specimens the dead leaves hang on through the winter. It is adapted to narrower streets than the red oak, as its habit of growth is not so spreading. On account of the tendency of the limbs to droop, particularly as they get older, it is desirable that a good strong leader should be developed, so that the lower limbs may be removed from time to time as conditions require. The pin oak thrives on wet and on heavy clay soils, as well as on a wide range of other soils. Figure 4 shows pin oaks, Norway maples, and ginkgos 18 years old on adjacent streets, and illustrates the rapid growth of this oak. At the time of planting these trees the pin oaks were thought to have the poorest location. This tree is adapted to regions 1, 2, 3, 4, 9, 10, and 11.

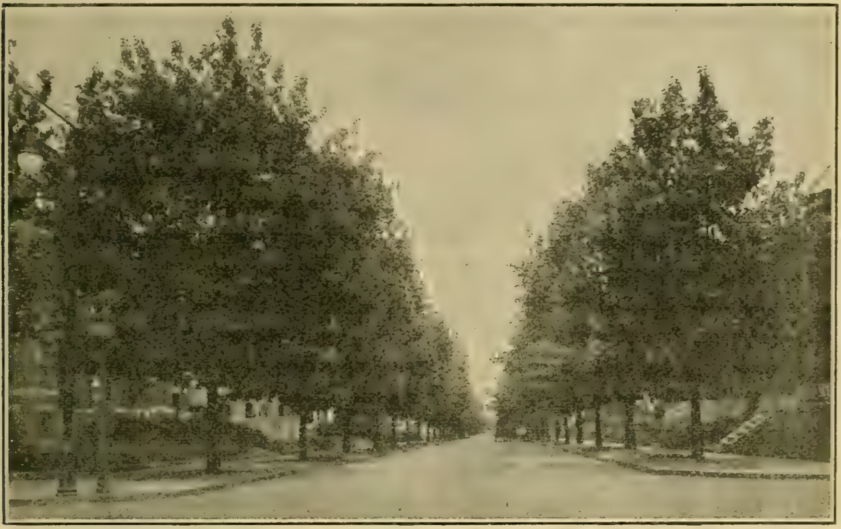
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FIG. 24.—A street shaded with red oaks, Washington, D. C.; midsummer.

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[1] *Quercus macrocarpa* Michx.

[2] *Quercus palustris* L.

The red oak[1] (fig. 24) is probably the best tree for street planting in regions 1, 9, 10, and 11 and is satisfactory in regions 6, 7, 8, and 12. It is a large, oval, open-headed tree of rapid growth. Under good conditions a young red oak will grow 4 feet in a single season. Like the other oaks it is slow in coming into leaf in the spring, but holds its foliage late in the fall. The leaves usually turn a brilliant red before they drop. It is comparatively free from insect and fungous attacks, and it is one of the few trees really suitable for planting close to the ocean, as it thrives on sandy lands only a few feet above high tide or within the reach of ocean spray.

The scarlet oak[2] is a large, open, round-headed tree. Its leaves are more deeply divided than those of the red oak. As its name indicates, the leaves turn a brilliant scarlet in autumn, being even more gorgeous than the red oak. This tree is adapted for street planting and is especially desirable for suburban conditions in regions 1, 9, and 10.

The swamp Spanish oak[3] is adapted to regions 11, 12, and 13. It belongs to the red-oak group, but is larger than the other oaks suggested for street planting. It is well adapted to suburban locations, but apparently it has not been tested under severe city conditions.

The valley oak[4] is a beautiful tree for regions 2 and 3 and the more favorable parts of region 5. When transplanted young, especially if taken from a pot, it is easily established where there is opportunity to water it for a few years.

The water oak[5] is frequently confused with the willow oak and the laurel oak, as these three oaks are not distinguished from one another except by close observers of trees. It is probably more used than any other tree in the cities of region 12 and the adjoining portions of region 11. It is the weed of the southern oaks and one of the weeds of the street trees of the Southern States. It is comparatively short lived and seems to be more subject to attacks of mistletoe and more easily affected by windstorms than the willow oak, the Darlington oak, and the laurel oak. The planting of this tree should be avoided, because it is less desirable than the other oaks mentioned.

The willow oak[6] (fig. 1), sometimes erroneously called the water oak, is one of the best of the quick-growing oaks for use in regions 11 and 12. It is frequently used with the water oak for street planting and in the mind of the average planter is confused with it. It is, however, a distinct tree, which can be distinguished readily from the water oak. It is longer lived and is its equal in every other respect. Trees of this variety which apparently have been planted about 80 years are found in excellent condition, while water oaks planted at the same time have either entirely disappeared or are showing

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[1] *Quercus maxima* (March.) Ashe (formerly *Q. rubra*).

[2] *Quercus coccinea* Muench.

[3] *Quercus rubra* L. (formerly *Q. falcata*, and certain forms separated by some botanists as *Q. pagodaefolia* Ashe).

[4] *Quercus lobata* Nee.

[5] *Quercus nigra* L.

[6] *Quercus phellos* L.

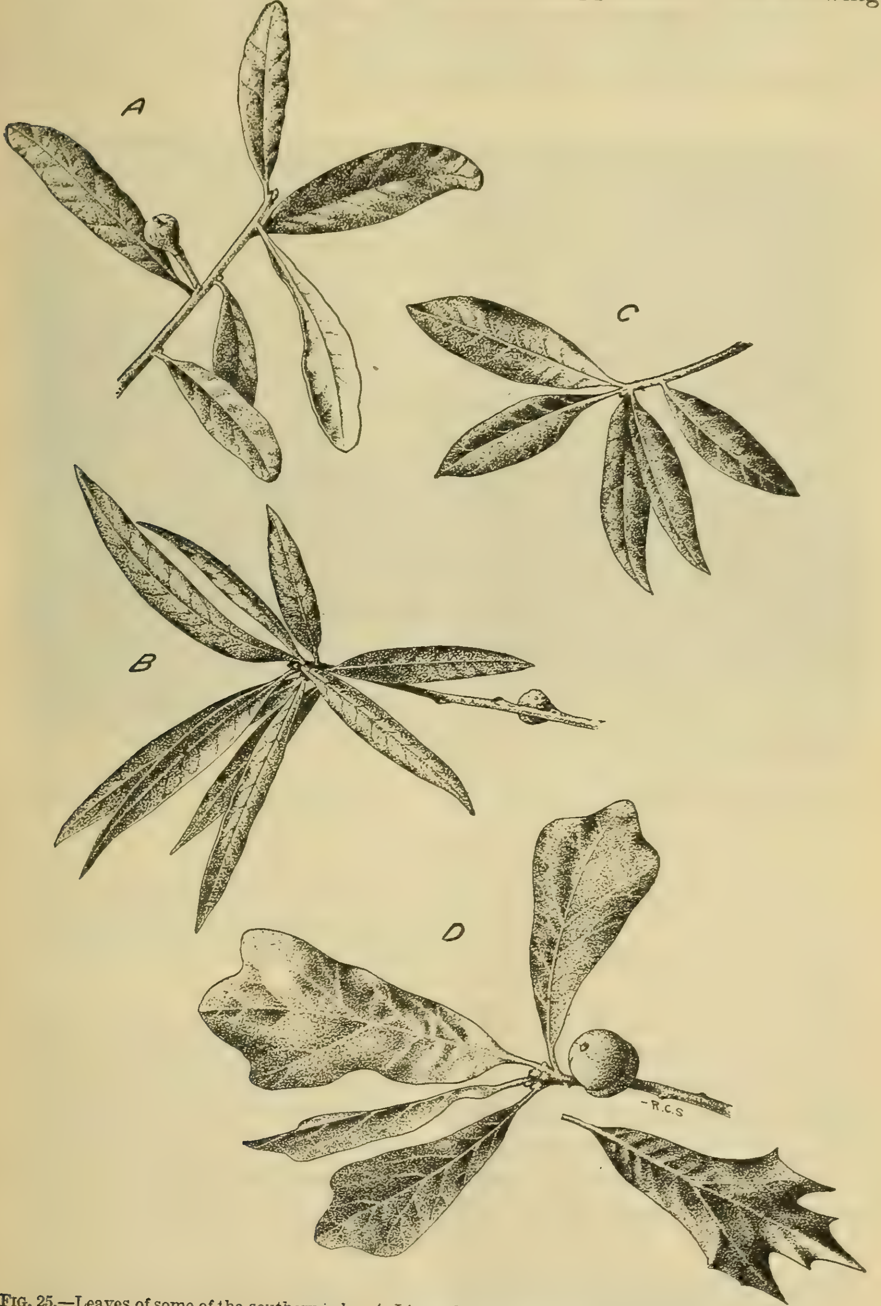

FIG. 25.—Leaves of some of the southern oaks; *A*, Live oak; *B*, willow oak; *C*, laurel oak; and *D*, water oak.

marked evidences of decline. Figure 25 shows the characteristic appearance of the leaves of these nearly related species of oaks. That the willow oak is readily transplanted in the South when of comparatively large size is proved by the success with which trees 12 feet high are dug from the woods and planted on the street (fig. 26). In the extreme South this tree is nearly half evergreen. Its foliage does not assume the bright colors of the trees of the red-oak class.

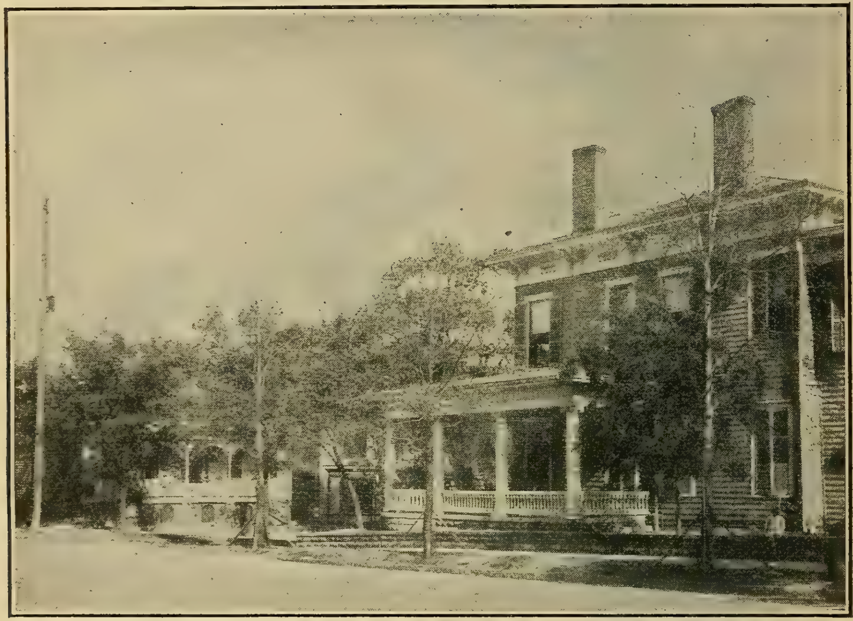

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FIG. 26.—Recently transplanted willow oaks, showing trees taken from the woods as they appeared near the end of the second summer. Montgomery, Ala.

PALM.[1]

Several varieties of palms are used more or less for street planting in regions 2, 3, 5, 12, and 13. Though sometimes effective as a formal street decoration (fig. 27), they can hardly be considered shade trees.

PALMETTO.

Palmettos, or sabals, abound in region 12 near the coast; succeed in regions 3, 5, and 13; live in region 2; but are seldom grown satisfactorily close to the Pacific coast. They can be used effectively for formal plantings along some streets, park drives, or in liberal central parking spaces in boulevards, but they are not useful as a substitute for shade trees. They should have their leaves and damaged roots cut off in transplanting and should be set about 3 feet deep in their new location.

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[1] The palms are treated on the basis of notes furnished by Dr. O. F. Cook, of the Bureau of Plant Industry.

The Carolina palmetto[1] is a native of and useful in regions 12 and 13, where it sometimes attains a height of 60 or 80 feet. It will thrive in regions 3 and 5, but is used less there.

The Texas palmetto[2] is especially valuable for southern Texas, where it is indigenous, and it is likely to succeed generally in regions 3, 5, and 12. It grows to a height of 40 feet and in appearance is quite distinct from the Carolina palmetto, the leaf segments being much broader and less drooping.[3]

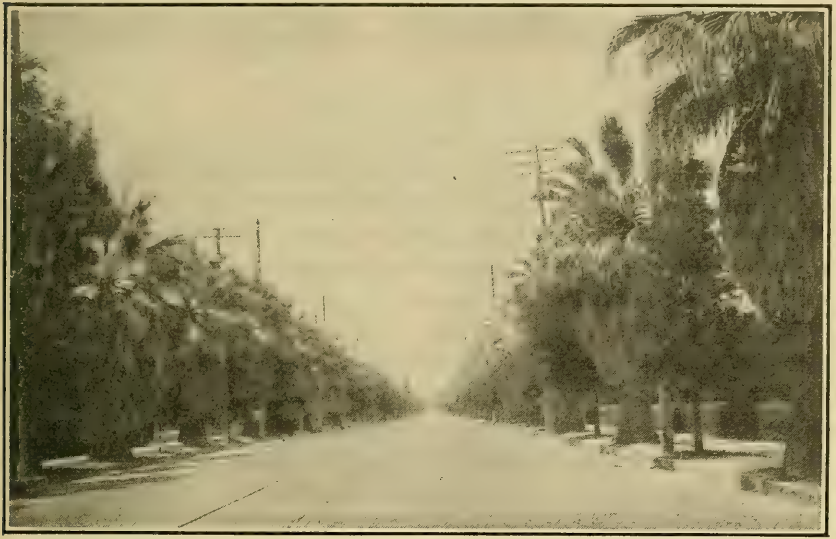

FIG. 27.—A formal planting on a city street. Palms with interplantings. Redlands, Calif., in midsummer.

The Victoria palmetto[4] is another hardy species, probably a native of Mexico, but grown for many years at Victoria, Tex. It is similar to the native Texas species and worthy of general planting in the same region. A feature of this species is that the persistent leaf bases remain alive and green for many years instead of turning yellow or brown, as in the Carolina palmetto.

WASHINGTONIA PALM.

Washingtonia palms are a very conspicuous feature of street and ornamental planting in southern California. Two species are represented, *Washingtonia filifera* Wendland and *W. robusta* Wendland. The first is a native of the canyons and barren slopes that surround the Coachella Valley of southern California, while the other species probably was brought by way of the Isthmus of Panama from the region of San Jose del Cabo, the extremity of Lower California, in the early days of travel. The name *robusta* alludes to the fact that this species grows much more rapidly in height than *W. filifera*, though the trunk is more slender. Both species are hardy and thrive well through regions 2, 3, and 5, and also in regions 12 and 13. *Washingtonia robusta* requires less heat than *W. filifera*, but both will endure several degrees of frost. Even in California *Washingtonia robusta* is distinctly preferable for localities near the coast. In the vicinity of San Diego the leaves of *Washingtonia filifera* become badly infested with a parasitic fungus that does not attack *Washingtonia robusta.*

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[1] *Inodes palmetto* (Walt.) Cook.

[2] *Inodes texana* Cook.

[3] The Texas palmetto. *In* Jour. Heredity, v. 8, no. 3, p. 123, pl. 1917.

[4] Cook, O. F. A new ornamental palmetto in southern Texas. *In* U. S. Dept. Agr., Bur. Plant Indus. Cir. 113, p. 11–14. 1913.

OTHER HARDY FAN PALMS.

The species most commonly used for street and ornamental planting in the California coast districts is the Chinese or windmill palm.[1] This palm has a slender trunk clothed with brown fibers, flat fan-shaped leaves, and rather straight radiating segments. The same species is hardy at New Orleans and Charleston, and even at Laurens, S. C., at an altitude of 600 feet, but it does not thrive in the sandy soil of Florida.

The vegetable hair palm,[2] a native of Spain, Sicily, and North Africa, is similar to the Chinese palm but smaller and more compact and with large, sharp spines on the petioles of the leaves. When young it suckers from the base, like the date palm, so that clusters of it may be formed.

The Guadeloupe Island palm[3] is one of the most popular species in southern California in the region of Santa Barbara, Los Angeles, and San Diego. This palm is a native of Guadeloupe Island, off the coast of lower California, and is not known to occur elsewhere in the wild state. It is well adapted to the cool coast climate of California, but not to the interior valleys. It is smaller than the Washingtonia palms, with a rather short trunk, 15 to 20 feet high, and a dense crown of fresh green leaves.

The California blue palm,[4] formerly placed in the same genus with the Guadeloupe Island species, is very distinct in habits as well as in general appearance, having bluish or grayish green leaves, strongly toothed petioles, and long, slender inflorescences. The trunk is very robust, often 2 to 3 feet in diameter, and is said to attain a height of 30 to 40 feet in Mexico. Several of these features are shared with the Washingtonia palms. It also has the ability to grow in the dry, hot interior valleys (regions 3 and 5). In Texas the blue palm has proved hardy at San Antonio, and even as far north as Austin.

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[1] *Trachycarpus excelsa* (Thunb.) Wendl.

[2] *Chamaerops humilis* L.

[3] *Erythea edulis* (H. Wendl.) S. Wats.

[4] *Glaucothea armata* (formerly known as *Erythea armata*). See Cook, O. F., Glaucothea, a new genus of palms from Lower California. *In* Jour. Washington Acad. Sci., v. 5, p. 236-241. 1915.

DATE PALM.

The Canary Island date palm[1] is the most popular palm for park or street planting, being more hardy than the true date palm, larger and more vigorous in growth, and producing no suckers from the base of the trunk. Well-grown specimens in the California coast districts (region 2) with trunks from 2 to 3 feet thick and immense crowns of spreading deep-green leaves are among the most imposing forms of plant life. Though less robust in other regions, the species is very hardy and adapted for planting anywhere in the palm belt (regions 3, 5, 12, and 13).

The true date palm[2] is adapted to the warmer parts of regions 3 and 5, but it is much inferior to the Canary Island species for ornamental use because the foliage is less attractive, due to its habit of sending out suckers from the base of the trunk.

THE COCONUT AND ITS RELATIVES.

The true coconut palm is confined to a narrow belt along the coast of southern Florida, but other species of cocos are planted in the coast districts of California. The species that is most prominent in park and street plantings around San Diego, Los Angeles, and Santa Barbara is usually known as *Cocos plumosa* or *Cocos romanzoffiana*, and is a rather tall, slender palm with a long-jointed trunk about 1 foot in diameter and long, spreading, feathery, deep-green leaves. Another series is represented by *Cocos yatay* and several similar species, often called *Cocos australis* in nursery catalogues. They have short, thick trunks, very glaucous grayish or bluish foliage, and fleshy edible fruits, highly flavored, somewhat like pineapples. These gray-leaved species are very hardy. Another coconut relative is the Chilean molasses palm,[3] which has a massive trunk 3 or 4 feet in diameter, specimens of which are growing at a few places in California.

OTHER PINNATE PALMS.

The amethyst palm, a native of Australia, is commonly planted in California. It usually appears in lists and nursery catalogues as *Seaforthia elegans* or *Archontophoenix alexandrae*, but it is now recognized as distinct from both of these species and has received a new name, *Loroma amethystina*. It is the only pinnate-leaved palm, except certain species of Phoenix and Cocos, that grows freely in the open air in the coast districts of California, from Santa Barbara to San Diego. In habit and general appearance Loroma is more like the royal palm, though with a smaller trunk and fewer leaves. The pinkish purple drooping inflorescence is very attractive and develops into a large cluster of scarlet berries.

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[1] *Phoenix canariensis* Hort.

[2] *Phoenix dactylifera* L.

[3] *Jubaea chilensis* Baill.

The royal palms, species of Roystonea, are perhaps the most striking ornamental members of the whole group. They can be grown in southern Florida and even exist in the wild state in some of the hammocks below Miami.

PEPPER TREE.

The California pepper tree[1] is much used in regions 2 and 3 and in the western part of region 5. It is a moderate-sized broad-headed tree with fine foliage, which gives it a light, airy appearance. During the fall and winter it is covered with scarlet berries, which in contrast with the persistent foliage produce a pleasing effect.

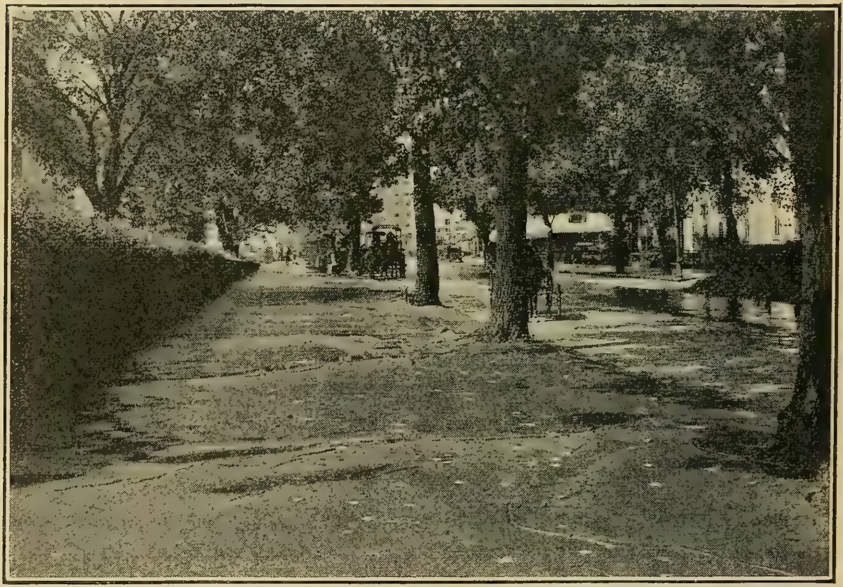

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FIG. 28.—A pavement heaved by the roots of poplar trees.

POPLAR.

Poplars are not desirable for street planting. Their wood is brittle and easily broken by ordinary windstorms, and their roots run near the surface and are likely to interfere with pavements, as shown in figure 28, while those of some varieties are especially liable to make trouble in sewers by filling them with a mass of fibrous roots if access is once gained. Vigorous root growth is encouraged by the moisture from a leak, and the roots ultimately find their way inside.

The southern cottonwood,[2] Carolina poplar, and the northern cottonwood[3] are so similar in their adaptability for street-planting purposes that they will be discussed together. They are easily propagated, easily transplanted, are quick growing, and where they reach maturity under normal conditions form very large oval-headed handsome trees, but under the artificial conditions existing in cities it is necessary to prune them quite severely when young to remove the long vigorous growths and make the heads more compact. This pruning stimulates more vigorous growth, which must be removed or they will form long branches with heavy tops, that are especially liable to be injured by windstorms. The more they are pruned the greater the tendency to an undesirable form of growth. They begin dropping their leaves early in the summer and lose them very early in the autumn. Their root growth is especially vigorous, so that they are liable to make trouble in sewers in the manner already mentioned. It is largely on this account that many cities prohibit the planting of these trees. Except in regions 6, 7, or 8 or in locations where smoke and fumes in the air prevent the growing of other trees, they should not be planted.

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[1] *Schinus molle* L.

[2] *Populus deltoides* Marsh.

[3] *Populus virginiana* Fouger.

The Lombardy poplar[1] is a tall columnar tree adapted for use on very narrow streets (fig. 14). It is short lived in many places, due largely to the European poplar canker, but otherwise is a satisfactory tree for these conditions in all parts of the United States. The trees may be planted as close together as 30 feet.

None of the other poplars have much to recommend them for street planting.

RUBBER TREE.

The rubber tree[2] is a large-headed handsome evergreen, suitable for regions 3 and 5 and the southern parts of regions 2 and 13 when the use of an evergreen tree is warranted.

SILK OAK.

The silk oak,[3] or Australian fern, is a large, handsome tree that succeeds well in regions 2, 3, and 13; also in region 5 if provided with a reasonable amount of moisture, as it stands drought remarkably well. It is covered in early summer with orange-colored flowers.

SWEET GUM.

The sweet gum[4] is adapted to regions 11, 12, and 13, especially on sandy lands. It forms an oval-headed, handsome tree with star-shaped leaves that assume a particularly brilliant hue in the autumn. It is better adapted to suburban conditions than to the heart of a city. Toward the northern limits of its successful cultivation it is difficult to transplant, while in the warmer sections of the country it can be moved with comparative ease. It should be transplanted only in the spring.

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[1] *Populus italica* (Du Roi) Moench.

[2] *Ficus elastica* Roxb.

[3] *Grevillea robusta* A. Cunn.

[4] *Liquidambar styraciflua* L.

SYCAMORE.

The sycamore,[1] also called the buttonwood and buttonball tree, is a large, open, spreading, quick-growing tree native along watercourses. It is adapted to regions 1, 2, 3, 4, 9, 10, 11, 12, and 13 and is worth testing in regions 5, 6, 7, and 8. Its habit of shedding its outer bark in large flakes, leaving the white new bark showing in large patches, makes it a conspicuous tree wherever grown. The fruits are balls 1 inch or more in diameter and are sometimes objected to because they make dirt when falling; also the shed bark is considered objectionable. It is such a strong-growing handsome tree and succeeds so well under city conditions that it is being planted more and more frequently. It will stand more pruning and shaping than any other street tree. Without pruning it is too large for ordinary streets unless spaced at almost double the usual planting distance, with the trees staggered along the street instead of being planted opposite. Its high head and open habit of growth are distinct advantages for street planting. Its foliage, too, is a light green, which gives an impression of airiness with the shade. It is subject to attack by a fungus that kills the leaves while still small or partially mutilates them, giving them an unsightly appearance. In some places this trouble is quite serious.

The California sycamore[2] is a native of California adapted to regions 1, 2, 3, and 4 and portions of region 5. It is similar in general characteristics to the sycamore.

The London plane tree[3] is one of the Old World forms of sycamore. According to Alfred Rehder,[4] "the true oriental plane is rare in cultivation, the tree usually planted under this name being *Platanus acerifolia*." It it more compact in habit of growth and has the other good qualities of the sycamore. It is being more and more used on city streets and is proving satisfactory in regions 1, 2, 3, 4, 9, 10, 11, and 12. It will probably succeed in the warmer parts of regions 6 and 7 and also in regions 5 and 8. It is a more desirable tree for ordinary use than the sycamore, on account of its more compact habit and comparative freedom from disease, though it is tender in the northernmost sections.

TULIP TREE.

The tulip tree[5] is also sometimes called the tulip poplar or yellow poplar, though the latter names are unfortunate, as the tree is not a poplar or even closely related to the poplars. It is a large, rapid-growing tree suitable for suburban conditions in regions 1, 2, 10, 11, and 12. The leaves are of unusual form, the upper half appearing to have been cut away, leaving a notch about where it would seem the middle of the leaf should be. The color is a light green. The roots are unusually soft and tender, and therefore the tree needs to be transplanted quickly and with great care. Small sizes should be planted, especially near the northern limits of growth. It should be transplanted only in the spring. If after transplanting it the top should die and a new vigorous shoot should put out from the root, it would be desirable to form a new top from this shoot rather than to transplant another tree.

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[1] *Platanus occidentalis* L.

[2] *Platanus racemosa* Nutt.

[3] *Platanus acerifolia* (Ait.) Willd.

[4] Bailey, L. H., ed. New York, 1916. Standard Cyclopedia of Horticulture, v. 5, p. 2707.

[5] *Liriodendron tulipifera* L.

CULTURE OF STREET TREES.

SELECTION OF INDIVIDUAL TREES.

Nursery-grown trees should be used for street planting, and they should have been transplanted at least every two years while in the nursery. This is to insure a thorough root pruning and the production of numerous fibrous roots close to the trunk. Trees not frequently transplanted form a few long roots that are largely cut off when the tree is dug. Trees growing in the woods form a few very long roots, and when an attempt is made to dig them only a little of the root next the trunk is obtained, while most of the roots, including the fibrous ones, are left in the ground. If woodland trees are wanted for street purposes, most kinds should be grown for a few years in a nursery in order to form a good root system before being planted on the streets.

In addition to a good root system, the tree should have a straight trunk for the variety, with a good set of branches, called the head, the bottom branches being from 7 to 9 feet from the ground. Trees which naturally head low should be started with a higher head than those varieties that have a tendency to an upright growth. A good head for a shade tree is a leader or upright branch with three or more side branches about equally spaced around the tree. The trees should be healthy, free from scars, and also free from evidences of insects or diseases. In the presence of insects, trees should be thoroughly fumigated along approved methods before leaving nurseries, to insure against the introduction and distribution of pests. Weakened vitality resulting from transplanting and subsequent neglect will frequently invite attack by bark-boring insects which seriously damage or kill the trees. Mulching and watering will often prevent this damage.

Opinion as to the size to plant differs somewhat, but for average conditions trees from 10 to 12 feet high and with trunks or stems from 2 to 2½ inches in diameter[1] are very satisfactory in most varieties used for street purposes. With such varieties as elms, sycamores, and some southern oaks, somewhat larger trees can be used equally well, while smaller trees would be better in the regions of limited rainfall both east and west of the Rocky Mountains and for tulip trees and sweet gums, especially in the northern portion of their range of usefulness.

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[1] Designated by nurserymen as "caliper."

PREPARATION OF HOLES.

Next to the selection of a proper variety, the preparation of the hole is the most important detail of street-tree planting. Because of the restricted area available for the spread of the tree roots, and owing to the artificial conditions imposed by the improvement of city streets, the soil provided for the feeding ground of the roots of the young tree must be liberal in quantity and of the best quality. From 2 to 3 cubic yards of soil should be provided for each tree. It is desirable to have at least 18 square feet of opening in the sidewalk, especially if it is of concrete or other impervious material. Trees will grow with smaller sidewalk openings, but they are not likely to thrive so well, and it is impossible properly to prepare a hole for planting a tree without disturbing at least this much surface soil. The proper depth of soil is from 2½ to 3 feet. A hole 3 feet deep large enough to hold 2 cubic yards of soil has a surface area of 18 square feet. A hole 6 feet long, 3 feet wide, and 3 feet deep will hold 2 cubic yards of soil, will have the smallest desirable surface area, and will be of such dimensions as will best conform to the usual sidewalk and roadway widths and thus not interfere with traffic.

The tree hole must be so drained that water will not stand in it. If the soil is so impervious as to hold water some artificial drainage must be provided. That portion of the depth of a hole that acts as a cistern for holding water is valueless as a feeding ground for roots. For every cubic foot of soil in the bottom of a hole that might thus be made valueless by standing water, 1½ cubic feet of soil should be added by increasing the length or width of it. Under no circumstances, however, should the depth of available feeding ground be less than 2 feet. The deeper the roots may be encouraged to grow, the less injury is likely to be experienced from drought.

The soil used should be topsoil from land that has been producing good crops. This should be well enriched with rotted manure, one part of manure to four of soil. The addition of such fertilizers as ground bone, tankage, fish scrap, or cottonseed meal at the rate of 1 pound to the cubic yard of soil is also helpful Commercial fertilizers containing mostly phosphoric acid obtained from other substances than ground bone are not to be recommended for use in the soil about the roots at planting time. When used they should form a surface application, worked into the soil after planting.

PLANTING.

If trees are shipped from a distance they should be taken at once on arrival to some point where the roots may be carefully covered with soil; there they should be unpacked and plenty of loose moist earth worked thoroughly around and over the roots as fast as they are taken from the box. This temporary covering of the roots is called "heeling in." (Fig. 29.) The tops may be either erect or laid almost on the ground in successive rows, the tops of one row lying over the roots of the previous rows, the object being to cover the roots thoroughly and keep them moist until the tree is wanted for permanent setting. Not a moment of exposure should be permitted between the box and the soil. If the roots appear dry, they may be dipped for a few minutes before heeling in in a tub of water or in thin mud.

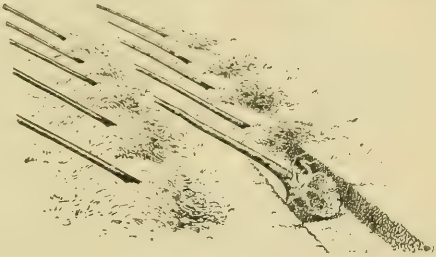

FIG. 29.—Trees properly "heeled in."

Trees in large quantities are often packed directly in cars with a small quantity of straw about the roots. When shipped in this way extra care (compare figs. 30 and 31) must be exercised in taking the trees to the point where they are to be heeled in. The wagon in which they are to be hauled should have a tight box, and wet canvas should be tied tightly over the load. The last is important, so that there may be no chance for the roots to dry.

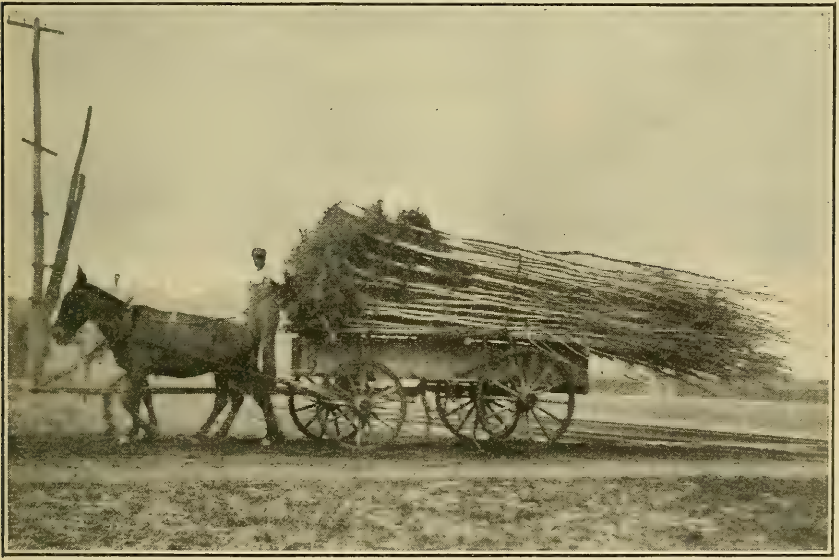

FIG. 30.—Trees handled in a careless manner. The roots should have been covered with wet canvas.

When taking trees from the ground where they have been heeled in to the place for planting, great care must also be exercised to see that the roots are not exposed to sun or wind, but are kept closely covered with moss, wet burlap, or canvas until planted. Lack of care in this matter is a greater cause of loss in tree planting than carelessness in any other particular. One city that has its own nursery and uses largely trees that are supposed to be difficult to move, but is careful about not exposing the roots for a moment (fig. 31), has a loss of less than 1 per cent. If the roots once dry the trees will die, and it takes but a short exposure to dry the roots. The holes should be prepared well in advance of planting, so that no time will be lost when conditions are right for putting the trees in the ground.

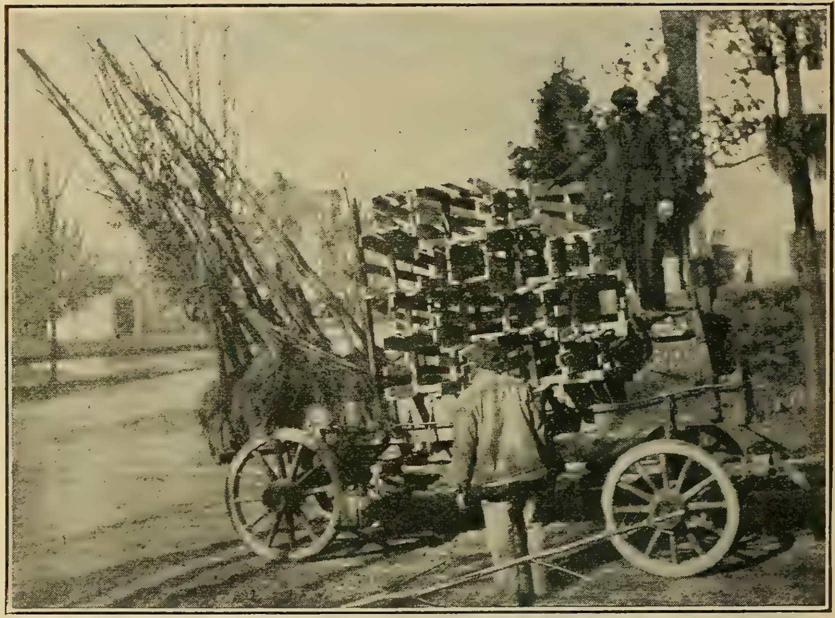
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FIG. 31.—A load of trees and tree boxes. The roots are packed in wet moss and a tree is not taken from the wagon until the planter and two shovelers are at the hole where it is to be planted.

In regions 1, 10, 11, 12, and 13 (fig. 17) the best time for planting deciduous street trees is the month or six weeks just preceding freezing weather in the fall. The other desirable time for planting is as soon after freezing weather is over in the spring as the ground is dry enough for the mechanical operations. This should be as early as possible, as the more opportunity there is for root growth before warm weather forces the top into growth, the better the results are likely to be. In regions 6, 8, and 9, where the ground freezes to a considerable depth, spring planting is to be preferred to fall planting unless it is possible to drench the soil thoroughly for a considerable distance around the trees at planting time and after that to mulch the soil thoroughly and also to protect the top from the effect of drying winter winds. Where mice abound they may be harbored in the mulch and may girdle the tree. This may be prevented by a collar of wire netting about the base of the trunk or by banking the earth about it. The death of trees at the time of transplanting is due to the drying out of either roots or tops before opportunity is given them to become reestablished in their new locations. This drying may be due to improper exposure at the time of digging or before packing (fig. 30), poor packing, prolonged delay in delivery, improper handling between unpacking and planting, or the existence of conditions conducive to excessive drying out of the plant after setting.

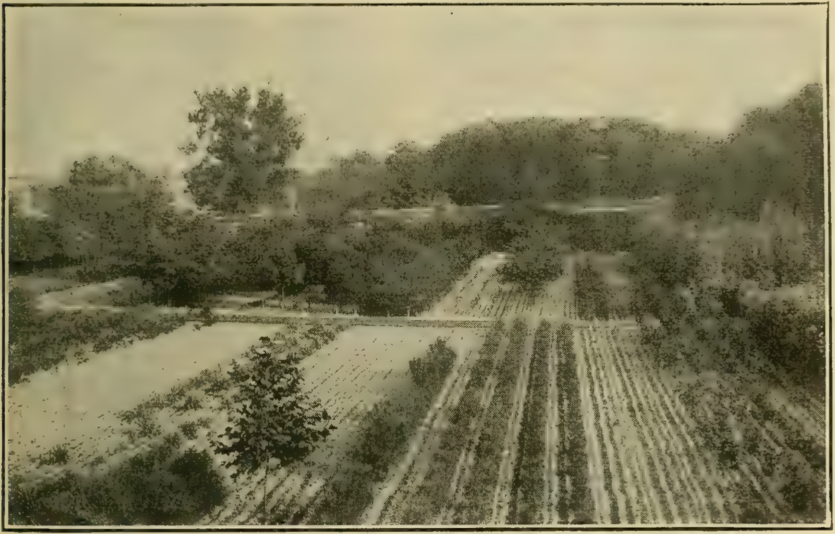
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FIG. 32.—A city nursery.

The atmosphere is continually claiming a tribute of moisture from all living plants, whether the plant is in leaf and growing or is dormant. Growing plants, and dormant plants under normal conditions, are able to replace this moisture by absorption through the roots. In climates where newly planted trees may obtain sufficient soil water to replace these losses by drying, fall planting is best. Where the plants are unable to get sufficient winter moisture, planting would better be done only in the spring. Where the soil freezes to a depth greater than that to which the plant roots extend, the supply of water is cut off from the roots and the tree will be killed by drying out through evaporation from the top. Where winter winds are very drying and the soil moisture is limited, evaporation from the top is likely to be in excess of that supplied by the roots and the tree is killed in the same way.

In regions normally adapted to fall planting, newly set trees may be killed by a dry autumn followed by a dry winter with high winds or by a cold winter with so little snow that the ground freezes below the roots. On the other hand, trees may often be successfully planted in the fall where such practice is not usually successful by thoroughly mulching the soil if freezing is the sole cause of the difficulty, or by

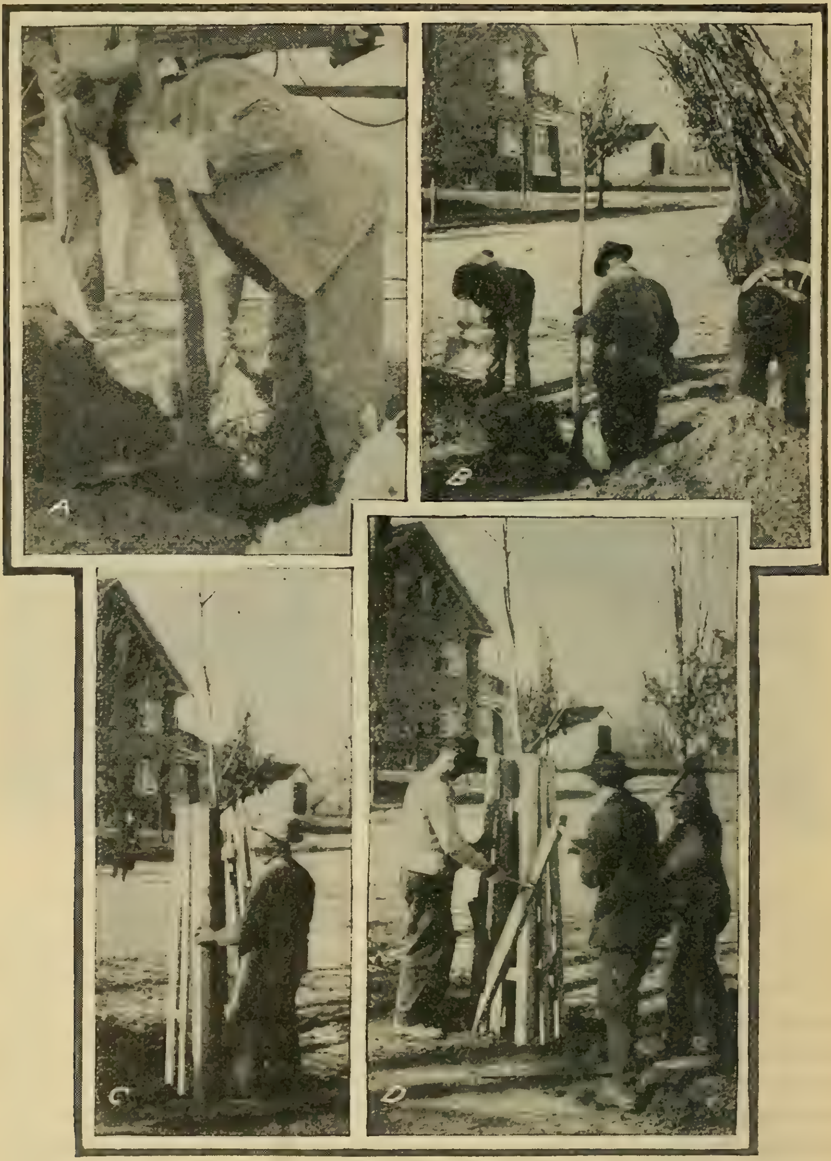

FIG. 33.—Setting a tree: *A*, Measuring from the curb to get the tree in line; *B*, filling the hole; *C*, placing the box; *D*, fastening the box.

drenching the soil thoroughly and then mulching well if lack of moisture and high winds are the causes of the trouble. Protection from the wind by wrapping the trunk and large limbs with burlap or some other protecting material is also desirable.

After a liberal opening has been made in the specially prepared soil the tree should be brought, preferably from the city's own nursery (fig. 32), but if such a nursery has not been provided, then from among the newly received trees that have been "heeled in," as already described.

If the tree has been well handled and the roots carefully protected it is ready for setting. It is desirable to immerse the roots in a thin mixture of clay and water just before putting it in the hole if there is suspicion that the roots have been exposed. This can be done before leaving the nursery or "heeling-in" ground, but the roots must be properly protected. Any mutilated ends of roots should be removed, the top should be severely pruned, as described later, and the tree should be placed in the hole in line with the other trees (fig. 33, *A*) and at such a height that after the filling is completed it will be about an inch deeper in the ground than it was before transplanting. The roots should be spread out in as near their original position as practicable, and soil should be carefully worked in about them with the fingers, so that each rootlet may come in contact with soil and not be crowded against other rootlets. When all the roots have been placed and covered the soil should be thoroughly trampled or tamped to bring the roots into as close contact as possible with it. Then more soil should be put in and the ground again tamped. Of course, in order to get satisfactory results the soil used for planting must not be too wet or too dry. If the soil is in such a state as to hold together in soggy masses and not spring apart again when squeezed in the hand, it is too wet for planting. If the soil is too dry, it will not stay in contact with the roots during the planting operations. A soil that is too dry may be well watered a day or two in advance of the planting, or if excessive dryness does not make it difficult to handle, the tree may be planted and then be thoroughly watered. After the watering 3 or 4 inches of loose soil should be spread over the wet ground in order to prevent undue evaporation. It should not be trampled or pounded in any way after the water is applied. If trees planted in moist retentive soils are watered after planting they should be provided with a mulch of similar earth. East of the Missouri River trees planted in soil that is in good condition usually do not need watering at the time of planting.

Trees planted from pots, cans, or boxes should have the ball of earth taken from the receptacle handled with care, so as not to break it further than to loosen some of the roots on the outside of the ball; then the soil should be as carefully placed about this ball and the loosened roots as about the roots of trees without balls. Trees planted with balls need no root pruning and little top pruning.

PRUNING.

At planting time the trees should be so pruned as to remove from one-half to three-fourths of the leaf buds. The head should be formed in the nursery, so that at planting time the only problem is how to reduce the amount of prospective growth the first season without destroying the form of the head. Specific directions are difficult, because different species of trees are so different in their character of growth. A species that is naturally compact in growth (fig. 34) should be pruned by removing whole branches rather than by having the ends of branches removed. One that is open and spreading (fig. 35) will probably need the shortening of the longer limbs as well as the removal of interior branches. The first pruning

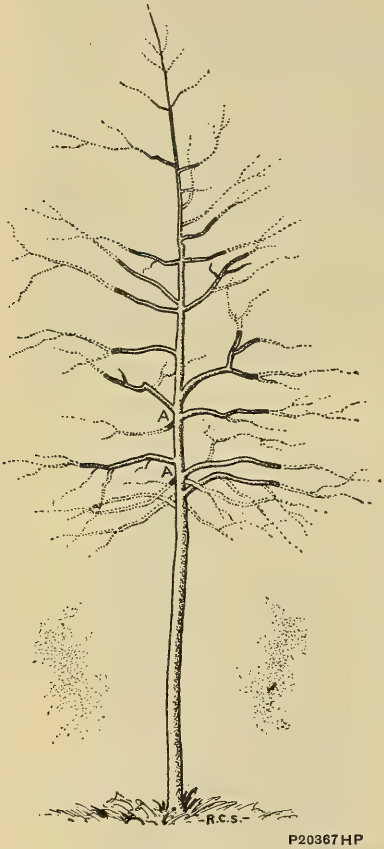

FIG. 34.—A pin oak trimmed for planting. Note the bad stubs (*A, A*) on the left-hand side of the tree.

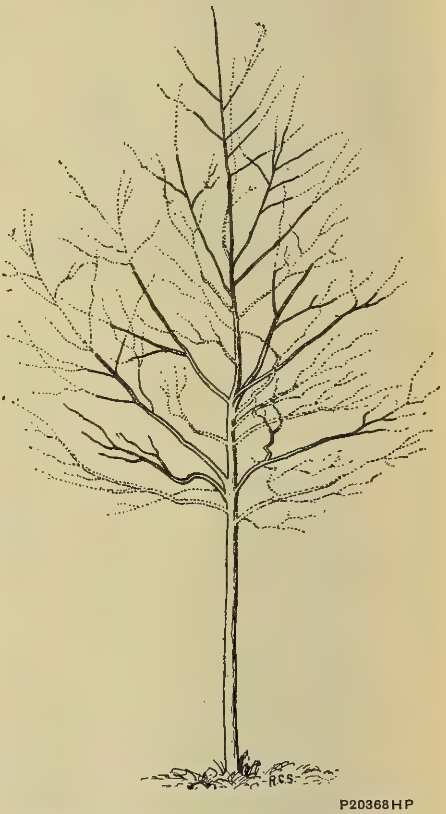

FIG. 35.—A sycamore trimmed for planting. Well pruned, without bad stubs.

should be the removal of such branches as can be spared. If enough buds can not be removed in this way without leaving the head too open, then the shortening of the branches must follow. It is usually necessary to remove three-fourths of the limbs to accomplish this. An expert can do this pruning or most of it more easily before the tree is planted than afterwards. Some additional pruning may be necessary after the tree is set.

In addition to the pruning of the top the roots may need some cutting. Any broken pieces or ends should be removed, making a clean cut with a sharp knife, as new rootlets put out more readily from a cleanly cut fresh surface than from ragged breaks. If the roots are very long, without branches or rootlets, it sometimes makes planting easier to cut off some of the ends. As roots are the braces by which a tree is supported in the ground, it is undesirable to reduce their length unless some positive good is to be gained by it.

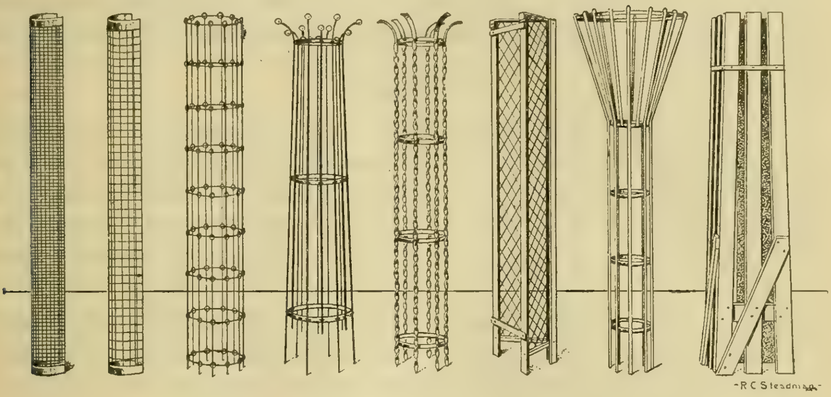

FIG. 36.—Types of tree guards.

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The best implement for cutting small limbs is a sharp knife, and for larger limbs a fine-toothed saw. Pruning shears are sometimes used, but they are likely to bruise the wood. If used at all, the blade should always be turned toward the tree so that the bruise made by the supporting bar will be on the portion cut off. Where branches are taken off, the cut should be close to the remaining limb, so that no suggestion of a stub will remain. (Figs. 34 and 35.) Where ends are cut from branches the cut should be just above a bud, and the remaining bud should point in the direction that it is desired the limb should grow.

STAKES AND GUARDS.

Under city conditions young trees need the support of a strong stake as well as protection for the trunk. Boys like to swing around small trees or see the tops fly up if bent to the ground. Men find them convenient hitching posts for their horses, and horses frequently like the taste of the bark or tear it off for the sake of having something to do.

Guards are of many forms (fig. 36), from stakes 2½ inches square set 3 feet in the ground and extending 6 feet above, with heavy netting placed about the tree and stapled to the stake, to heavy wooden cribs of four stakes and intermediate slats and wrought-iron patterns of many forms.

The trees should be firmly secured to the tops of the guards so that they will not swing against them in the wind and be rubbed. This is best done by securing the tree in place in the guard by two loops of pieces of old garden hose, soft leather, or rope, in such a way as not to bind the tree too tightly while keeping it from swinging much or rubbing. The essentials are a firm support for the tree while young with reasonable protection of the trunk from careless depredations until the tree has reached a diameter of 6 inches or more.

LATER CARE.

If after planting, the season is dry and it becomes necessary to apply water, the ground should be soaked thoroughly, and as soon as it has dried sufficiently to work up loosely it should be hoed or raked to make a good earth mulch. A mulch of strawy manure or litter may be used in place of the earth mulch if desired. The watering should not require repeating for a week or more.

If the weather becomes warm soon after planting and the trees come into leaf, wither, and droop, further pruning may save them. The reason for the difficulty is probably that the growth of the top has been greater than the newly formed roots can support; therefore the additional pruning is likely to restore the balance between the top growth and root growth. At least three-fourths of the remaining young wood should be removed. This may leave the tree looking almost like a bean pole, but if it induces a vigorous root growth the top can easily be re-formed.

Young trees should have an annual inspection, and all crossing branches and any that are not well placed to form a good head should be removed. Attention should be given also to all forks, and where two branches start almost parallel to one another or at a small angle, making a fork liable to split apart as the tree grows, one branch should be removed. Where three branches start from almost the same point there is little likelihood of their splitting apart, but with only two growing at a less angle than 30° there is liable to be trouble in the case of most kinds of trees. On trees on which few but long shoots form, it may be well to remove the ends of such shoots. As a rule, it is undesirable to use for street planting trees with this kind of growth. Young trees should be trained into a desirable shape by the use of a pruning knife each year, so that a saw will not be necessary later. Some trees have a tendency to form too dense a head. The interior branches of these should be removed and the head made as open as possible while the work can be done with a knife. No attempt should be made to alter the natural form of a tree but only to insure its best development. A skillfully pruned young tree will show no evidences of the pruning after three or four years.

CARE OF MATURE TREES.

PRUNING.

It is very little trouble to train a tree into a good shape by using the pruning knife while the limbs are small, but it is usually difficult to re-form a tree after it has grown to maturity. One who understands tree growth, however, can often reshape the top of a neglected tree to advantage, though many who make a business of tree trimming know so little about it that they do more harm than good. More mature trees have been hurt by severe pruning than have been helped. Of course, dead or dying wood should be removed whenever it is found, no matter what the age of the tree. This should be done by cutting off the limb back to the nearest healthy crotch. A limb should not be cut off square across (fig. 21) unless the tree is apparently in a dying condition and the whole top is treated thus in an attempt to save its life. In such a case, a second pruning should follow within two years, at which time the stubs left at the first trimming should be cut off in a proper manner near the newly started limbs. Healthy silver maples and willows are frequently cut in this way, but the maples in particular would better be cut down at once than to subject the public to the dangers of the insidious decay that almost always follows such an operation on these trees and completes their destruction promptly.

Trees that have been neglected a long time frequently have interfering or crossing branches, or are too low headed or too densely headed for the place where they are growing. Defects of this kind may be at least partially remedied. The removal of limbs by cutting them off at a crotch in such a manner that the wound is parallel with the remaining branch (fig. 37) inflicts the least possible damage. Such a wound in a healthy tree will soon heal over if the cut is made through the slight collar or ring that is nearly always present at the base of a branch. The closer this cut can be made to the trunk the better the appearance when the cut is healed. The closer the cut the larger the wound, but the difference is unimportant if the wood is well protected until it is healed. These operations are entirely different in purpose and result from the ''heading in'' or ''heading back'' so often practiced under the guise of tree pruning, either from a false notion of forming a top or for the passage of wires.

Changing the form of a tree by pruning should not be attempted. Each species has its own form or forms, and no attempt should be made to change or distort a tree from its normal habit of growth. Successful pruning will accentuate rather than disguise a tree's characteristics.

All cuts should be made so that no stubs or protuberances are left to prevent quick healing. Small wounds need no after treatment if the cut is well made. Large wounds should have the wood of the center of the cut well protected to prevent decay until the new growth has had an opportunity to heal over the cut. An application made to the center of the cut to preserve the wood should not be permitted to come near the cambium layer or inner bark, especially of soft-wooded trees like the tulip and magnolia, as the oil or other substances contained in the paint, tar, or other covering may spread to the cambium layer and kill it. It is well not to make any application within half an inch of the outside of the wound unless the coating has been thoroughly tested.

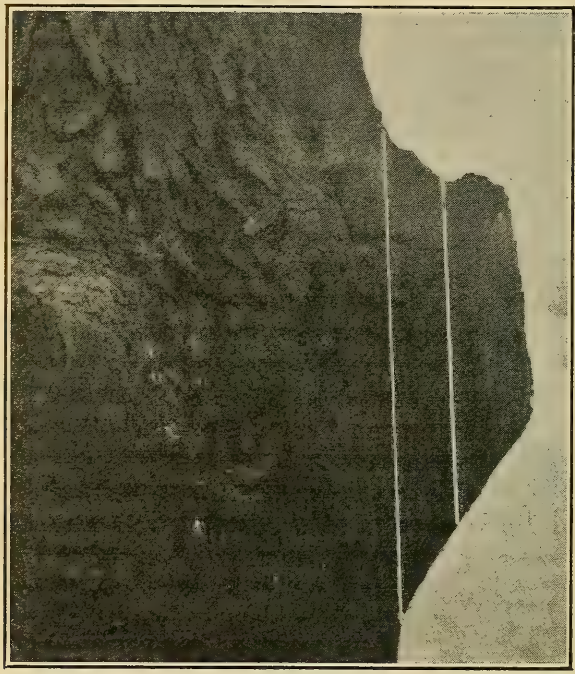
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FIG. 37.—Part of a tree trunk showing proper and improper methods of removing old limbs. Although healing has started on the stub (at the right) it is likely to proceed very slowly. The nearer the cut is to the tree the larger the wound but the less conspicuous the stub will be when healed.

Dead wood should be entirely removed, the cut being made through good live tissue. Removing such wood frequently exposes decayed cavities, usually from bad stubs or injuries which have started decay that has followed back to the main limbs or the trunk. The treatment of such cavities is the province of tree surgery and is discussed in another publication.[1]

One source of trouble with a large tree that has developed with two trunks or branches instead of three or more is the liability of their splitting apart in the crotch. This is especially characteristic of the elm. Careful attention to the early pruning of trees may eliminate this defect, but when it exists in mature trees it is frequently advisable to connect the branches by a strong chain (fig. 18) in order to prevent the limbs from being torn apart.

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[1] Collins, J. F. Practical tree surgery. *In* U. S. Dept. Agr. Yearbook, 1913, pp. 163–190, pl. 16–22. Published as Yearbook Separate 622, obtainable from the Superintendent of Documents for 10 cents in coin.

FEEDING.

It is difficult to do anything to stimulate the growth of street trees after they are once started, because usually the only uncovered area over the roots is the small opening immediately about the tree; hence, the importance of supplying the best of soil well enriched at the time of planting. Sometimes a stimulation is desirable, which can be accomplished by dissolving one-half to 1 pound of nitrate of soda in 50 gallons of water and applying from 1 to 25 gallons of the liquid, depending on the size of the tree. Unless the soil is damp at the time of application water will be needed immediately afterward. This material should be applied only when the tree is in full leaf and growing. If applied when the tree is dormant it is likely to be leached from the soil before it is absorbed. If applied late in the season, that is, within three months of freezing weather, it would likely stimulate a late growth that would be liable to be killed the following winter and might make the whole tree more susceptible to injury from cold.

Water is one of the great needs of city trees, as the ground surface is often almost completely roofed over with water-tight coverings. It is usually a help for the pavement washings to drain into the parking space where the tree is planted. If a curb is placed about the parking space, frequent, regular watering is necessary where the ground is thoroughly covered with water-tight pavements.

Where growing under suburban conditions, that is, with streets partially pervious to water, liberal parking spaces, and adjoining lawns, street trees will respond to all extra care given the near-by open spaces, whether parkings, lawns, or gardens. If these are well cared for the trees should have ample sustenance from them without any direct applications.

In order to prevent the soil about a tree from being packed too hard by trampling it is frequently desirable on business streets to cover the soil about it with an iron grating.

SPRAYING.

Street trees, like all other forms of vegetation, are subject to attacks of insects and diseases. Because of the unfavorable conditions under which they grow, spraying for biting and sucking insects and suitable treatment for borers or other burrowing insects require especially careful attention.

In addition to a number of troubles common to street trees in general, each species is liable to troubles of its own; hence, the need of competent supervision by a trained man with an efficient outfit rather than leaving the work to individual initiative.

Because of the height which many street trees attain a powerful outfit is required to spray them properly. One capable of maintaining a pressure of 200 pounds per square inch is desirable. The type of spray required for tall trees is different from that used on fruit trees and other low plants. For low trees the ideal spray is a mist within a few feet of the nozzle, application being accomplished by having the nozzles near the foliage to be treated. For tall trees it is desirable that the liquid should leave the nozzle in a solid stream, which is broken into spray as it passes through the air. The material has to be projected with sufficient force to reach the highest trees before being entirely converted into mist, as it is impracticable to extend the nozzles into the trees to reach the farthest portions, as is done with fruit and other low trees. The spray can not be applied as uniformly as a mist, but it is impracticable to climb into the tops of shade trees to cover every part with a cloudlike spray. On the other hand, the mist spray is better for small trees, as much injury may be done to low trees or to the lower branches of high trees by the force of the stream from high-pressure outfits.

It is estimated that in practice up to 95 per cent of the attacking insects can be killed with insecticides carefully applied by the stream method under high pressure.

In addition to the mechanical problem of satisfactorily covering high trees with insecticides or fungicides there is the problem of selecting materials that will be effective against the insects and diseases and at the same time will not disfigure the paint or stone work of adjacent buildings with which the materials must inevitably come in contact in street-tree spraying. It frequently happens that the most effective remedies must be rejected because of the damage they would do to buildings and that less efficient materials must be used.

Whitewashing the trunks of trees is a useless and unsightly practice—useless, as it does not prevent the attacks of insects, and unsightly, because it makes the trunks of the trees obtrusive when they should be inconspicuous.

Banding with cotton or proprietary preparations may occasionally be useful, but because such applications are so seldom helpful and because some of the preparations result in injury due to constriction of the trunks, it should not be resorted to except upon special recommendation of an entomologist familiar with the existing conditions.

Details as to enemies to be expected, methods of treatment, and materials to be used may be found in other publications [1] or may be obtained by correspondence with the nearest State agricultural experiment station or with the United States Department of Agriculture.

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[1] See list on following pages.

PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO DISEASES AND INSECTS AFFECTING SHADE AND ORNAMENTAL TREES.

AVAILABLE FOR FREE DISTRIBUTION.

Control of Root-Knot. (Farmers' Bulletin 648.)
The San Jose Scale and Its Control. (Farmers' Bulletin 650.)
The Bagworm, an Injurious Shade-Tree Insect. (Farmers' Bulletin 701.)
The Catalpa Sphinx. (Farmers' Bulletin 705.)
The Leopard Moth: A Dangerous Imported Enemy of Shade Trees. (Farmers' Bulletin 708.)
The Oyster-Shell Scale and the Scurfy Scale. (Farmers' Bulletin 723.)
The White-Pine Blister Rust. (Farmers' Bulletin 742.)
Carbon Disulphid as an Insecticide. (Farmers' Bulletin 799.)
The Gipsy Moth and the Brown-Tail Moth and Their Control. (Farmers' Bulletin 845.)
Common White Grubs. (Farmers' Bulletin 940.)
The Blights of Coniferous Nursery Stock. (Department Bulletin 44.)
Forest Disease Surveys. (Department Bulletin 658.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

The Mistletoe Pest in the Southwest. (Bureau of Plant Industry Bulletin 166.) Price, 10 cents.
The Death of Chestnuts and Oaks Due to Armillaria mellea. (Department Bulletin 89.) Price, 5 cents.
New Facts Concerning the White-Pine Blister Rust. (Department Bulletin 116.) Price, 5 cents.
The Huisache Girdler. (Department Bulletin 184.) Price, 5 cents.
Report on the Gipsy Moth Work in New England. (Department Bulletin 204.) Price, 30 cents.
A Disease of Pines Caused by Cronartium pyriforme. (Department Bulletin 247.) Price, 5 cents.
Food Plants of the Gipsy Moth in America. (Department Bulletin 250.) Price, 10 cents.
Dispersion of Gipsy-Moth Larvæ by the Wind. (Department Bulletin 273.) Price, 15 cents.
The Cottonwood Borer. (Department Bulletin 424.) Price, 5 cents.
Solid-Stream Spraying against the Gipsy Moth and the Brown-Tail Moth in New England. (Department Bulletin 480.) Price, 15 cents.
Protection from the Locust Borer. (Department Bulletin 787.) Price, 5 cents.
Principal Insects Liable to be Distributed on Nursery Stock. (Entomology Bulletin 34, n. s.) Price, 5 cents.
The Locust Borer. (Entomology Bulletin 58, part 1.) Price, 5 cents.
Additional Data on the Locust Borer. (Entomology Bulletin 58, part 3.) Price, 5 cents.
The San Jose or Chinese Scale. (Entomology Bulletin 62.) Price, 25 cents.
Report on Field Work against the Gipsy Moth and the Brown-Tail Moth. (Entomology Bulletin 87.) Price, 35 cents.

The Importation into the United States of the Parasites of the Gipsy Moth and the Brown-Tail Moth. (Entomology Bulletin 91.) Price, 65 cents.

The Dispersion of the Gipsy Moth. (Entomology Bulletin 119.) Price, 20 cents.

The Green-Striped Maple Worm. (Entomology Circular 110.) Price, 5 cents.

The Oak Pruner. (Entomology Circular 130.) Price, 5 cents.

The Dying Hickory Trees: Cause and Remedy. (Entomology Circular 144.) Price, 5 cents.

Flour Paste as a Control for Red Spiders and as a Spreader for Contact Insecticides. (Entomology Circular 166.) Price, 5 cents.

Three Undescribed Heart-Rots of Hardwood Trees, Especially of Oak. (Journal of Agricultural Research, vol. 1, No. 2.) Price, 25 cents.

A Serious Disease in Forest Nurseries Caused by Peridermium filamentosum. (Journal of Agricultural Research, vol. v, No. 17.) Price, 10 cents.

The Chestnut Bark Disease. (Separate 598, from Yearbook of the Department of Agriculture for 1918.) Price, 10 cents.

Practical Tree Surgery. (Separate 622, from Yearbook of the Department of Agriculture for 1913.) Price, 10 cents.

Forest Tree Diseases Common in California and Nevada. (Forest Service Unnumbered Publication.) Price, 25 cents.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 817
Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. PROFESSIONAL PAPER May 12, 1920

OBSERVATIONS ON THE LIFE HISTORY OF ASCARIS LUMBRICOIDES.

By B. H. Ransom, *Chief*, and W. D. Foster,[1] *Junior Zoologist, Zoological Division.*

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HISTORICAL SUMMARY.

The results of experiments by Lutz (1888), Epstein (1892), and other investigators, together with various considerations of general and special nature, have led to the acceptance of the belief to the extent that it has been taken as an established fact that *Ascaris lumbricoides* and *Ascaris suum*, parasites of man and the pig, respectively, have a direct life history and require no intermediate hosts in their cycle of development. Recent work by Stewart (1916–1918), however, has shown that the life history of *Ascaris* is not so simple as commonly supposed, and he has made the highly interesting and important discovery that if a rat or a mouse is fed *Ascaris* eggs many of the larvæ which escape from the eggs in the intestine wander out of the alimentary tract, and, apparently aided by the circulation, reach the liver and later the lungs, meanwhile undergoing considerable growth and development.

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[1] This paper was written after the death of Mr. Foster, which occurred October 6, 1918, but in view of his participation in the investigations upon which the paper is based his name appears as joint author.

Many years ago Davaine (1863) observed newly hatched larvæ in the feces of rats a few hours after feeding them *Ascaris* eggs, but Stewart was the first to discover that in these animals not all the young worms that hatched were promptly eliminated but that some penetrated the wall of the alimentary tract and reached other locations in the body, meanwhile increasing in size and undergoing certain developmental changes. He determined further that the larvæ in the lungs do not remain there, but migrate up the trachea and can be found in the mouth. On the basis of this fact Stewart (1916b) in one of his papers suggested that rats and mice that had become infected by swallowing the eggs of *Ascaris* might later transfer the parasites to human beings or pigs by contaminating food with saliva containing the young worms. Stewart, however, in continuing his investigations found that after the larvæ passed up the trachea they then passed down the esophagus, reached the intestine, and tended to accumulate in the cecum. Finally they passed out of the intestine in the feces without undergoing any material change in size or structure from that presented by the stage attained in the lungs.

Certain experiments with pigs had failed to result in definite proof that these animals became infected with *Ascaris* through swallowing the eggs, and Stewart therefore offered the hypothesis that rats and mice act as intermediate hosts in the life cycle. According to this hypothesis *Ascaris* eggs contained in the feces of infested human beings or pigs after reaching the infective stage are swallowed by rats or mice. In these hosts the young worms hatching from the eggs migrate from the intestine to the lungs and back again to the intestine and reach a stage of development considerably in advance of that characterizing the embryo within the egg. They then pass out of the body of the rat or mouse in the feces. If food contaminated with the feces of infested rats or mice is eaten by human beings or pigs the worms thus reach their final host, in whose intestine they settle down and develop to maturity. The completion of the life cycle thus requires, according to Stewart's explanation, an alternation between two hosts—the final host, man or pig, and the intermediate host, rat or mouse.

Lane (1917) and Low (1918) have given a number of reasons for doubting the validity of Stewart's explanation of the life cycle of *Ascaris*, and the present writers in a preliminary note (Ransom and

Foster, 1917) also indicated that the theory that rats and mice act as intermediate hosts is not tenable. In fact it has become quite evident that human beings and pigs become infected with *Ascaris* as a result of swallowing the eggs, the behavior of the parasites in rats and mice being simply the expression of an abortive development in animals imperfectly adapted as hosts. Our investigations have shown that the parasites migrate through the lungs in the guinea pig, rabbit, sheep, goat, pig, and presumably man, as well as in the rat and mouse. Very definite evidence has been obtained showing that the animals in which the parasites reach maturity become infected by swallowing the eggs, that the larvæ after hatching migrate out of the intestine into the lungs and back to the intestine, undergoing a development similar to that which occurs in rats, mice, and other unsuitable hosts. Having returned to the intestine, following this migration, some of the young worms may be eliminated in the feces and perish, but others may establish themselves and complete their development to the adult stage.

Stewart's very striking discoveries therefore have not upset our former views of the life history of *Ascaris* so far as concerns the spread of the parasite from infested human beings and pigs to others, but they have added some highly important facts to our former imperfect knowledge. Stewart, furthermore, has shown that the young worms not only migrate through the lungs, but in so doing may set up a serious pneumonia that in experimentally infected rats and mice is liable to be fatal. The present writers, in a preliminary note already referred to (Ransom and Foster, 1917), noted the occurrence of pneumonia in the pig as well as in smaller animals as a result of the invasion of the lungs by *Ascaris* larvæ, and Stewart in some of his later papers (1917, 1918) also reported *Ascaris* pneumonia in pigs. It is evident that *Ascaris* may likewise affect the lungs of human beings, and it is an interesting fact that Mosler (according to Leuckart, 1867) and Lutz (1888) in experiments in feeding *Ascaris* eggs to human subjects observed certain lung symptoms undoubtedly to be attributed to *Ascaris* infection, though of course the significance of the symptoms was not appreciated at the time. It is not unlikely that many cases of lung disease of obscure nature may have as an etiological factor the invasion of the lungs by *Ascaris* larvæ. Lung affections in children especially should be studied with reference to this possibility. In the case of pigs the frequent and serious condition commonly known as "thumps" is undoubtedly often the result of *Ascaris* infection. Stewart's contributions to our knowledge of the life history of *Ascaris* may accordingly prove the starting point from which an important advance can be made along the line of disease prevention.

PROBABLE IDENTITY OF ASCARIS LUMBRICOIDES AND ASCARIS SUUM.

The common intestinal roundworm of man (*Ascaris lumbricoides*) and the corresponding parasite of the pig (*A. suum* Goeze or *A. suilla* Dujardin) are morphologically indistinguishable and probably are specifically identical. Whether or not infection of man from worms harbored by the pig, and vice versa, commonly occurs is unknown and it has not yet been shown by experiment whether or not the offspring from worms harbored by one host can reach fertile maturity in the other. Although there is no good reason for considering the two forms to be distinct, in the present paper the pig *Ascaris* will be referred to as *A. suum* and the human *Ascaris* as *A. lumbricoides*, so that it may be clear in any given case whether the parasite came from a pig or from a human host.

EGG STAGE OF ASCARIS.

INCUBATION.

When deposited by the adult female in the intestine of the host animal the egg of *Ascaris* is in an early stage of segmentation. Segmentation progresses during the passage of the egg through the intestine. If the egg is not promptly eliminated in the feces of the host, however, segmentation does not continue and development of the embryo comes to a standstill. Martin (1913) found by experiments in vitro that at the body temperature of the host segmentation progresses rapidly up to a certain limit, but development of the embryo is completed only at lower temperatures. Because of the inhibiting effect of the body temperature it is necessary for the eggs to pass out of the intestine of the host before they can develop to the infective stage. Outside the body the development of the eggs is chiefly influenced by three factors—temperature, moisture, and oxygen supply. At low temperatures development proceeds slowly and may stop entirely if the temperature is low enough, so that the time required for the embryo to develop to the final stage reached in the egg may vary from a few days to many months and possibly several years.

Martin (1913) found the optimum temperature for the development of the eggs of *Ascaris vitulorum* (of the ox) and *A. suum* to be about 33° C. We have noted that a considerable proportion of the eggs of *A. suum* kept at this temperature contain fully developed embryos at the end of 10 days, and practically all complete their development within a month. In the absence of moisture, development is inhibited and extreme dryness may ultimately destroy the vitality of the eggs. The moisture requirements, however, are slight. Ross (1916) found that eggs of *A. lumbricoides* placed on glass slides and left exposed to the sun in India for 6 weeks contained actively motile embryos at the end of that time. We have kept the eggs of *Ascaris suum* in an incubator at 37° C. until they became extremely dry, but there was no continuation of the development when the eggs were moistened and removed to a lower temperature. Though dryness may be fatal to the eggs of *Ascaris*, it is certain that under most climatic conditions there is sufficient moisture in the environment (usually the soil) into which the eggs come after elimination from the host to enable development to proceed, at least intermittently, if not continuously. The inhibiting effect of the lack of moisture and the stimulating effect of its presence may be easily observed by placing newly deposited *Ascaris* eggs in water on a slide under a cover glass, noting the stage of development and then allowing the preparation to dry naturally. In a few days, if water is added to the preparation, little or no further development will be seen to have occurred, but if the slide is kept moist for a few days it will be found that development proceeds again. By moistening or drying development may be thus favored or hindered.

As shown by Hallez (1885), oxygen is necessary to the development of *Ascaris* eggs. This is indicated by the fact that eggs in water covered by a film of oil fail to develop. We have observed that if the eggs are kept in stoppered bottles filled with water development is inhibited. According to Fauré-Fremiet (1912), the determining cause of segmentation is the oxidation of hydrocarbon reserves stored up in the egg, for which, of course, a supply of oxygen is necessary.

Bacterial decomposition of the surrounding medium inhibits development and may be destructive to the vitality of *Ascaris* eggs.

INCUBATING ASCARIS EGGS FOR EXPERIMENTAL USE.

To secure the rapid development of a high percentage of *Ascaris* eggs to the final stage for experimental purposes, various methods of incubation have been used by different investigators. Martin (1913) obtained the most satisfactory results by placing the eggs in a 2 per thousand solution of hydrochloric acid and incubating at a temperature of 33° C. Hallez (1885) spread the eggs over the surface of earth in a flowerpot which was kept moist by standing in water. After trying various methods and media we have adopted the following: The adult worms after collection are sorted by sex and size and only the larger females are retained. These are slit lengthwise and pinned out in a tray of water. The uteri are dissected out and removed. Twenty worms will furnish all the eggs that can be incubated in three petri dishes 13.5 centimeters in diameter. The uteri are snipped with scissors into as small pieces as possible and are then rubbed up with a small quantity of 2 per cent formalin in a glass mortar. This forces the eggs out of the small sections of uterus and to some extent breaks up the clumps of eggs, so that they will spread evenly over the bottom of a petri dish. The material thus obtained is then poured into 3 petri dishes, enough 2 per cent formalin being added to fill the dishes with fluid to a depth not exceeding one-fourth of an inch. These cultures are incubated at a temperature of 33° to 34° C. To secure proper aeration of the medium it is stirred with a glass rod every 2 or 3 days. About one-third of the fertilized eggs will be found to contain motile, fully developed embryos in 10 days, and practically all will be fully developed by the end of a month.

In using the entire uterus of the worm for preparing the culture many incompletely formed eggs are introduced. This may be avoided to some extent by using only the terminal portions of the uteri, and it is preferable to do so if for any reason it is desired to keep the number of incompletely formed eggs in the culture down to a minimum. To obtain eggs for the study of their development, Wharton (1915) kept the female worms in Kronecker's solution (sodium chlorid 6 grams, caustic soda 0.06 gram, distilled water 1,000 grams), in which the worms remain alive and active from 6 to 12 days. The eggs deposited were collected each day from the bottom of the vessel in which the worms were kept.

LONGEVITY OF ASCARIS EGGS.

Ascaris eggs may remain alive for long periods. Davaine (1863) kept the embryos in eggs of *A. lumbricoides* alive for 5 years. Morris (1911) noted that in human feces which had been kept 2 years in 2 per cent formalin some of the eggs of *A. lumbricoides* present contained actively motile embryos. Two months later there was an apparent increase in the number of eggs containing active embryos. Epstein (1892) produced experimental infections with eggs of *A. lumbricoides* that had been kept in a culture of feces for a year. We have kept *Ascaris suum* eggs alive for many months and there is no reason to suppose that the length of time the eggs of the pig *Ascaris* may retain their vitality is any less than in the case of the human *Ascaris.* Because of the great longevity of the eggs it is evident that soil exposed to continual pollution with feces of infested human beings or pigs may become in course of time very heavily laden with living *Ascaris* eggs. It is also evident that places not exposed to fresh contamination may nevertheless retain their infection for years.

RESISTANCE OF ASCARIS EGGS TO CHEMICAL AGENTS.

The shells of *Ascaris* eggs are very impermeable to as well as insoluble in many chemical reagents. Formalin solutions make excellent media in which to incubate the eggs. A 10 per cent solution of potassium bichromate also makes a good culture medium. Many observations have been made as to the slight effect upon *Ascaris* eggs of various substances that are very destructive to protoplasm. For example, Galli-Valerio (1914) succeeded in developing the eggs to a stage containing vermiform embryos in solutions of sulphuric, hydrochloric, nitric, and acetic acids 50 per cent or less in strength, in saturated solutions of copper sulphate, iron sulphate, and copper acetate, and in 50 per cent antiformin. In experiments with full-strength antiformin we have found that the shells of eggs containing motile embryos are dissolved by this substance, but the thin membranous lining of the shell remains intact. Kept in antiformin within this membrane the embryo may still be active at the end of 5 days, but if the membrane is burst by applying pressure the embryo is instantly killed by the antiformin.

We have kept *Ascaris suum* eggs containing vermiform embryos alive for several hours in carbolic acid, and embryos were still active in eggs kept 5 weeks in crude petroleum and in petrolatum. In eggs kept 10 weeks in crude petroleum no living embryos were seen, and the shells of most of the eggs were collapsed, but in most of the eggs kept the same length of time in petrolatum the embryos were active and very few eggs with collapsed shells were observed.

In view of the resistant nature and impermeability of the shell of the *Ascaris* egg it is evident that ordinary methods of disinfection by the application of chemical agents in more or less dilute solutions are of little or no use in preventing the spread of infection. According, however, to results obtained by Wigdor (1918) and unpublished results of experiments by Dr. Raffensperger and Miss Cram, phenol solutions are destructive to the eggs of *Ascaris* (or *Toxascaris* in the case of Wigdor's experiments), and it is possible that phenol disinfectants may prove useful under some conditions in the control of *Ascaris*.

AVENUE OF INFECTION WITH ASCARIS.

Infection with *Ascaris* has been shown by repeated experiment to be the result of swallowing eggs containing fully developed embryos. The possibility of natural infection in other ways than by the swallowing of eggs, however, is not absolutely excluded. Martin (1913) injected eggs of *Ascaris equorum* containing active embryos beneath the skin of a guinea pig. When the animal was killed 41 days later many empty eggshells were found at the site of injection, showing that the eggs had hatched. The fate of the embryos was not determined. Martin made similar experiments with the eggs of *A. equorum* and *A. vitulorum* on a dog, a rat, and guinea pigs, with similar results. We have repeated Martin's experiments, using eggs of *A. suum* containing active embryos (Experiment No. 13).

Our experiments show that if introduced beneath the skin *Ascaris* eggs will hatch and that within a few days the larvæ will appear in the lungs, reaching the same stage of development as they would in a similar time if the eggs had been swallowed.

Under natural conditions there appears to be little likelihood of infection through the skin. As noted elsewhere in this article, *Ascaris* eggs sometimes hatch outside the body, but it is not known whether the newly hatched larva can penetrate the uninjured skin. The fact that the hatching of the eggs outside the body is a relatively rare occurrence indicates that infection through the skin, if it occurs at all, is likely to be very unusual. Possibly, however, eggs in contact with the skin on some parts of the body may hatch much more commonly than they do away from the body. Other possibilities can also be imagined, such as the introduction of the eggs into wounds and into the vagina.

Apart from the question of the possibility of infection through the skin, the hatching of *Ascaris* eggs when injected subcutaneously and the prompt migration of the larvæ to the lungs are of interest as demonstrating that the action of the digestive juices is unnecessary for the hatching of the eggs, and that the larvæ are probably aided by the circulation in their migration to the lungs.

HATCHING OF ASCARIS EGGS.

When *Ascaris* eggs containing fully developed embryos are swallowed they pass through the stomach unhatched; at least the great majority do. In view of the occasional hatching of *Ascaris* eggs outside the body in various media it is evidently possible that hatching in the stomach may sometimes occur. In fact, Martin (1913) observed empty eggshells and free embryos in the stomach contents of a rat and a mouse fed *Ascaris* eggs experimentally. The eggshells, however, were irregularly torn and all the embryos were dead. Martin believes that the apparently hatched eggs seen by him in the stomachs of experimental animals were eggs that had been crushed by the teeth of the animals in chewing the material with which the eggs were fed. In any event it appears quite certain that hatching in the stomach is not a normal occurrence.

Davaine (1863) fed a large number of eggs of *A. lumbricoides* containing fully developed embryos to a rat which was killed 12 hours later. In the small intestine he found unhatched eggs, eggs in the process of hatching, and free embryos. In another experiment a rat was fed large numbers of *Ascaris* eggs and numerous active embryos were afterwards observed in the feces as well as unhatched eggs, and eggs in the process of hatching. Davaine also placed *Ascaris* eggs in small glass tubes closed at the ends with gauze and fed them to a dog. These were recovered in the feces 2 days later. The eggs in early stages of segmentation were unchanged, free embryos were found in the tubes, but eggs containing active embryos were no longer present. As Davaine in his experiments never found eggs hatching in the stomach, and only in the intestine, he concluded that hatching does not occur until after the eggs have passed to the small intestine. It was also shown by Davaine that some of the newly hatched larvæ may pass out of the body in the feces, and he supposed that this regularly occurs if the animal that has ingested the eggs is one in which the parasites can not attain their complete development.

By experiments in vitro Davaine (1858) found that the gastric juice of the rabbit and the dog will not digest the shell of the egg of *Ascaris lumbricoides* even when allowed to act 3 or 4 days. De Klug (1907) also observed that artificial gastric and tryptic digestion was without effect upon the shells of *Ascaris* eggs. Martin (1913) likewise found that various natural and artificial digestive juices do not dissolve the shells of *Ascaris* eggs.

From the experiments and observations of Davaine, Martin, and others it would appear that the hatching of the egg is the result of efforts on the part of the contained embryo. The shell is split and the embryo emerges through the opening, pressing apart the edges of the opening as it emerges. What factor or factors determine hatching is uncertain. Davaine (1859, 1863) reached the conclusion that the gastric juice does not act on the shell of the *Ascaris* egg and expressed the opinion that although the intestinal juices do not dissolve the shell they soften it so that the embryo, stimulated to great activity by the temperature of the body of the host, is able to break through it. Martin (1913) reaches the following conclusions:

> Hatching depends upon three factors: First, complete development of the embryo; second, a surrounding medium that is alkaline or neutral in reaction; and third, a temperature that is the same as the temperature of the host of the parasite. Digestive juices do not dissolve the eggshell. Hatching does not occur in the stomach, because of its acidity; it does occur in the intestine because of its alkalinity.

In support of his conclusions as to the factors that determine hatching, Martin has recorded the results of a considerable number of experiments in vitro with various media. The writers, in experiments on the eggs of *Ascaris suum* in vitro, have been unable to cause hatching with any regularity. We have observed that a few eggs will hatch in vitro in almost any medium, including acid as well as neutral and alkaline media, not only at the temperature of the body but at lower temperatures. The vast majority of the eggs, however, do not hatch, although the contained embryos may remain alive and active. Apparently, therefore, the factors that influence the hatching of *Ascaris* eggs are yet to be determined.

Although we are ignorant of the determining cause of hatching, nevertheless we can reach certain conclusions as to the place and manner in which hatching occurs, as follows: When *Ascaris* eggs containing fully developed embryos are swallowed they do not regularly hatch in the stomach, but pass to the small intestine, where they begin to hatch within a few hours after the eggs are swallowed. The eggshell is not dissolved by the digestive juices, the embryo being released by a split in the shell through which it emerges by its own efforts. *Ascaris* eggs may hatch not only in animals in which the parasites can develop to maturity, but apparently in almost any mammal that swallows the eggs, provided the embryos within the eggs have reached a stage in which they are ready to hatch.

LARVAL STAGES OF ASCARIS.

MIGRATIONS OF LARVÆ IN BODY OF THE HOST.

It has been stated that in artificially infected rats, mice, and other animals newly hatched *Ascaris* larvæ may be recovered in the feces within a few hours after the eggs have been swallowed. Stewart (1916–1918), however, discovered that not all the larvæ were thus eliminated, but that some migrated out of the alimentary tract into other parts of the body and soon appeared in the liver. Stewart (1916a) found larvæ in the liver of a mouse (in dilated blood capillaries) which died four days after being fed eggs of *A. lumbricoides*. In this animal the larvæ had also reached the lungs (in the air vesicles). He found larvæ of *Ascaris marginata* in the liver of mice within 24 hours after administration of the eggs, none having yet appeared in the lungs (Stewart, 1918a, p. 194). Our experiments show that the larvæ after leaving the lumen of the intestine soon appear in the liver, and may be found there before they are evident in the lungs. For example, a mouse killed 51 hours after feeding with *Ascaris suum* eggs showed numerous larvæ in the liver, but none could be found in the lungs or spleen. Frequently as late as five days after feeding *Ascaris* eggs to mice we found larvæ only in the liver, none having yet reached the lungs. In one instance, eight days after it had been fed *Ascaris suum* eggs, a mouse was killed and larvæ were found only in the liver.

The newly hatched larvæ of *Ascaris suum* measure about 0.2 to 0.3 mm. in length. In the liver the larvæ may grow to a length of 0.86 mm. (mouse nine days after infection, lungs and various other organs also infested), reaching a stage of development similar to that of larvæ of corresponding size in the lungs.

Ascaris larvæ commonly disappear from or at least become scarce in the liver within from 4 to 10 days after infection, but we have found numerous larvæ in the liver of a mouse as late as 23 days after feeding *Ascaris suum* eggs. Apparently they leave the liver more rapidly in the case of guinea pigs and rabbits than in the case of mice; though this may be only apparent. Given the same number of larvæ in the small liver of a mouse and in the relatively large liver of a guinea pig or rabbit, the presence of larvæ in the former case might be easily detected, and in the latter only with difficulty or not at all. We have actually never seen them in the liver of a guinea pig. Most of our guinea pigs, however, were killed or died later than 4 days after feeding. Rabbits that were killed or died 8, 10, 86, and 99 days after feeding *Ascaris suum* eggs showed no larvæ in the liver. Rabbits killed 3 and 5 days after feeding showed numerous larvæ in the liver, 0.2 to 0.25 mm. long in the first case and 0.23 to 0.45 mm. long in the second.

With reference to the path of migration from the intestine to the liver and thence to the lungs, it has been pointed out (Stewart, 1917a, p. 227) that there are two apparently possible ways in which the larvæ can get from the intestine to the liver and later to the lungs. Assuming that inasmuch as the thickness of the newly hatched larva is three times the diameter of a red blood corpuscle of the mouse, it can not pass through the lumen of an ordinary capillary vessel. (1) The larva enters a mesenteric venule and is carried to the liver, where it is arrested at the entrance to the hepatic capillary plexus. Acute fatty degeneration of the liver tissue enables the larva to penetrate along the capillaries between the degenerated columns of the liver cells to the hepatic venules. The larva then passes in the hepatic vein and vena cava to the heart, and by the pulmonary artery to the lung. There it is arrested by the pulmonary capillaries. Hemorrhages of the arterioles result and the larva penetrates into the air vesicles. (2) The newly hatched larva travels up the bile duct and reaches the bile capillaries of the interlobular zone. Working its way through the degenerated liver tissue, it reaches a hepatic venule and continues its course as in the first case.

Observations made by the writers are in harmony with the suggestion that migration from the intestine to the liver may be by way of the portal system, and from the heart to the lung by the pulmonary artery. Owing to the difficulty of avoiding possible contamination with larvæ from other locations than the vessels from which the blood was taken in our experiments (Nos. 11 and 12), the results of the experiments should not be accepted as in themselves sufficient proof of the migration of the larvæ in the path indicated. From general considerations, however, Stewart's first suggestion seems more likely to be correct than the alternative suggestion. As noted elsewhere, it is quite probable that some larvæ migrate along a route different from either of those suggested by Stewart.

Stewart (1916a) found larvæ in the lungs of a mouse within 4 days after it had been fed *Ascaris lumbricoides* eggs. We have found larvæ in the lungs of the rabbit and guinea pig as early as 3 days after feeding *Ascaris suum* eggs. In rats, mice, guinea pigs, and rabbits they may be found commonly in the lungs in large numbers from 4 to 6 days after infection. As they become numerous in the lungs they disappear from or become scarce in the liver. In size the larvæ observed by us in the lungs varied in length from 0.2 or 0.3 mm. (that is, the same as the newly hatched larva), up to 1.8 mm. Larvæ of the latter length have been observed in the lungs of rabbits 10 days after infection, and slightly smaller in the lungs of a mouse 13 days after infection. There is considerable variation in the size of larvæ found in the lungs at the same time. For example, larvæ varying in length from 0.29 to 0.6 mm. were observed in the lungs of a mouse 7 days after infection; in another mouse from 0.6 to 1.12 mm. 10 days after infection; in a guinea pig from 0.3 to 0.45 mm. 4 days after infection; in another guinea pig 0.35 to 0.83 mm. 5 days after infection; in another guinea pig 0.63 to 0.93 mm. 6 days after infection; in a rabbit from 0.23 to 0.48 mm. 5 days after infection; and in another rabbit 0.9 to 1.8 mm. 10 days after infection. We have observed that living larvæ may still be found in the lungs of a mouse as late as 23 days after infection, and we have found dead larvæ encapsulated in the lungs of a rabbit killed 86 days after infection, and in the lungs of a pig we have observed degenerated larvæ 65 days after infection.

The larvæ in the lungs (Stewart, 1916a) enter the air vesicles and wander into the trachea. He found them in the bronchi as early as the seventh day and in the trachea as early as the eighth day after infection. We have found a larva in the trachea of a rabbit 3 days, and in the trachea of a guinea pig 5 days, after infection. They are often numerous in the trachea 6 days after infection. The smallest observed in the trachea was 0.23 mm. long (rabbit, 3 days after infection). In a pig 7 days after infection larvæ were observed in the trachea, varying from 0.67 to 1.33 mm.

From the trachea the larvæ enter the pharynx. We have recovered larvæ from the mouth of an experimentally infected animal.

From the pharynx the larvæ pass down the esophagus. They have been observed in the esophagus as early as 6 days after infection (guinea pig, rabbit). The latest we have observed them in the esophagus has been 10 days after infection (rabbit). No doubt they may be found still later. In a pig, 9 days after infection, we have observed larvæ in the esophagus, and there were numerous larvæ in the esophagus of a kid that died 27 days after a first feeding and 10 days after a second feeding with *Ascaris suum* eggs. In a mouse 9 days after infection the larvæ in the esophagus varied from 0.9

to 1.45 mm. in length, and in a rabbit 8 days after infection from 0.99 to 1.33 mm. in length.

Migrating *Ascaris* larvæ pass from the esophagus through the stomach into the small intestine. We have observed them in the stomach of a guinea pig 7 days, and of rabbits 8 and 10 days, after feeding with *A. suum* eggs. Numerous larvæ were present in the first and fourth stomachs of a kid that died 27 days after a first feeding and 10 days after a second feeding with *Ascaris suum* eggs. The shortest time after infection for the return of migrating *Ascaris* larvæ to the small intestine that we have observed has been 6 days. In a guinea pig a few larvæ were observed in the small intestine 6 days after *Ascaris suum* eggs had been fed. In the rabbit they have been found in the small intestine as early as 8 days, and in the mouse as early as 9 days after infection. In a mouse fed *Ascaris suum* eggs 10 days before, larvæ were found in the small intestine measuring from 0.83 to 1 mm. in length. In mice the larvæ have been observed to persist in the small intestine as late as 23 days after infection. In rats, mice, guinea pigs, and rabbits the larvæ continue their migrations down the alimentary tract and pass into the large intestine. They can be found commonly without difficulty in the cecum during a certain period. We have seen them in this location in mice as early as 9 days and as late as 23 days after infection. Those seen on the ninth day measured 0.38 to 0.46 mm. in length; larvæ measuring 0.75 to 1.45 mm. were present in the cecum of a mouse 10 days after infection. Stewart (1916c) found the larvæ in the large intestine of mice 9 to 12 days after they had been fed the eggs of *Ascaris suum*. He also found them in the feces of mice as early as 9 days and as late as 12 days after infection, and in the feces of a pig Stewart (1918b) found dead larvæ 11 days after infection. We have observed them in the feces of the mouse as late as 13 days after infection, their length ranging from 1.2 to 1.75 mm.

Summarizing the observations that have been made on the migrations of *Ascaris* larvæ in rats, mice, guinea pigs, and rabbits, it may be stated that they can be found in the liver as early as 2 days after infection, in the lungs and trachea as early as 3 days after infection, in the esophagus and small intestine as early as 6 days after infection, and in the large intestine and in the feces as early as 9 days after infection. They may still be present in the liver, lungs, and alimentary tract 23 days after infection, but, as first pointed out by Stewart, rats and mice usually become free from the parasites in a little more than 2 weeks after infection, and we have found the same to be true also of guinea pigs and rabbits.

Ascaris infestation in rats, mice, guinea pigs, and rabbits accordingly persists only 2 or 3 weeks. After the first elimination of unhatched eggs and newly hatched larvæ in the feces that takes place during the first day or two after the eggs are swallowed, the larvæ that have migrated through the lungs begin to pass out of the body in the feces about 9 days after infection and have usually all or practically all been eliminated in less than 3 weeks after infection. During their stay in the body they may increase in size from an original length of 0.2 to 0.3 mm. to a length of nearly 2.5 mm. (Stewart), most of them, however, reaching a length not exceeding 1.75 mm., and some being not more than 1 mm. long when eliminated in the feces.

Stewart (1916a) remarked upon the occurrence of larvæ in the spleen. We have occasionally observed larvæ in the spleen, 2 being present in the spleen of a mouse examined 23 days after infection, 8 in the spleen of a mouse examined 19 days after infection, and 1 in the spleen of a mouse examined 9 days after infection—in this case measuring 0.36 mm. in length. As a rule, however, the spleens of our experimental animals, which were commonly but not always examined, showed no larvæ, so that this organ may be considered an unusual location. In one case a larva was found in the thyroid gland of a mouse 23 days after infection. In another mouse 13 days after infection larvæ were found under the peritoneum in various places in the abdominal cavity, including the Fallopian tubes. Probably the larvæ occur rather infrequently in the spleen, thyroid, and under the peritoneum of the abdominal cavity, but in our examinations, except in the case of the spleen, we rarely looked for them in these places. The kidneys have been examined repeatedly, but no larvæ have been found in them.

It has been suggested that the larvæ migrating from the intestine reach the liver by way of the portal vein, continue to the heart in the hepatic veins and vena cava, and from the heart to the lung in the pulmonary artery, and it is possible that most of the larvæ follow this course. Evidently, however, in view of their occurrence in the spleen, thyroid, etc., some of the larvæ at least may migrate along other paths. How they get to the spleen, thyroid, and under the peritoneal lining of the abdominal cavity has not been explained. The possibility is not excluded that in their migrations from the intestine some of the newly hatched larvæ are carried in the lymphatics more or less directly to the heart and reach the lungs without passing through the liver. Perhaps some of these larvæ, together with others that pass very rapidly through the liver and are soon carried in the portal circulation to the heart and lungs before they have increased much in size, get into the pulmonary veins, notwithstanding the intervening capillaries, are returned to the heart, and are then distributed to various parts of the body.

Since the foregoing was written more than a year ago, two papers by Yoshida (1919) have come to hand. In the latter of these papers Yoshida gives the results of experiments from which he concludes that the larvæ of *Ascaris* migrate actively through the tissues to the lungs after hatching in the intestine, and he considers that the possible carriage of the larvæ in the circulation, if it does occur at all, is of secondary importance. He would also explain the presence of larvæ in the spleen, kidneys, and various other locations in which he has found them in addition to the lungs and liver, as resulting from an active penetration of the larvæ through the tissues unaided by the circulation.

DEVELOPMENT IN THE INTESTINE.

After reaching the small intestine following their migration through the lungs, *Ascaris* larvæ, if in a suitable host, settle down and develop to maturity. It appears, however, that some of them may pass on out of the intestine and perish, just as they do in the case of rats, mice, guinea pigs, and rabbits. Stewart (1918b) noted dead *Ascaris* larvæ in the feces of a pig 11 days after feeding the eggs. Accordingly, even though the host is one in which the parasites can reach maturity, not every larva that succeeds in completing the cycle through the lungs is able to establish itself in the intestine. This would seem to be the probable explanation of the fact that pigs fed the eggs of *Ascaris suum* experimentally and afterwards showing evidence of lung invasion by the larvæ, may, when killed after a lapse of time sufficient for the development of the parasites to maturity or to a stage approaching maturity in the intestine, be found to harbor only a few worms or none at all. Such failures have been noted by us. For example, a pig 27 days old was fed numerous eggs of *Ascaris suum*, October 4, 1917. Another lot of eggs was fed to this pig November 10. On November 17, or 44 days after the first feeding and 7 days after the second, the pig was killed. The liver and lungs showed numerous petechiæ similar to those occurring in other experiment animals in association with the invasion of these organs by *Ascaris* larvæ, but no larvæ were seen in the preparations examined. In the small intestine there were 8 immature *Ascaris*, 5 of which were measured and found to range from 60 to 88 mm. in length. Another pig, from the same litter, that was fed *Ascaris suum* eggs September 22, when 15 days old, died 7 days later and showed numerous larvæ in the lungs, trachea, and pharynx, those in the trachea ranging in length from 0.67 to 1.33 mm. (Experiment No. 19).

It is quite likely that the worms found in the intestine of the first pig came from the eggs fed 44 days before, but the result of the experiment by itself can not, of course, be considered conclusive proof that development of *Ascaris* in the intestines of pigs follows the ingestion of the eggs, nor that the larvæ which mature in the intestine first migrate to the lungs and back again before they settle down in the intestines. Other possibilities are open. For example, if it is accepted that the larvæ migrate through the lungs of pigs as they do through the lungs of small experiment animals, which is shown to be the case by the result of the experiment with the second pig and other similar experiments, it is yet possible that the larvæ might be eliminated in the feces after migrating through the lungs, as in rats, mice, guinea pigs, and rabbits, and later be picked up again by the pigs and only then become established in the small intestine. Thus the mode of infection would be similar to that assumed in the theory of the rat and mouse as intermediate hosts, except that the pigs would act as their own intermediate hosts, becoming finally infected by larvæ that had once passed through their own bodies instead of through the bodies of rats or mice.

In our experiments there were also possible sources of infection other than the eggs that were fed. There may have been stray rats or mice about, or their feces may have been present in the feed, and in view of the small number of worms found in the intestine of the pig in the experiment recorded above, it may be supposed that they could have come from such a source. Owing to the difficulty of controlling experiments on pigs we have not yet succeeded in obtaining sufficient evidence from experiments on pigs alone to demonstrate conclusively that infection results from the ingestion of eggs and the subsequent migration of the larvæ through the lungs and back to the intestine, where they become established and develop to maturity. That such, however, is a fact we believe is proved by the following:

The migration of the larvæ through the lungs occurs in animals of various species that ingest the eggs irrespective of whether such animals are suitable hosts of the adult worms. This has been shown to be true of the rat, mouse, guinea pig, rabbit, goat, and pig. In man symptoms have been described by Mosler (in Leuckart, 1867) and Lutz (1888) that indicate the migration of *Ascaris* larvæ through the lungs.

The *Ascaris* embryo prior to hatching from the egg is admirably fitted to withstand the hardships of existence outside the body of a host, and may remain alive for years, protected by the eggshell. The larva after reaching the stage in which it is eliminated from unsuitable hosts, such as rats and mice, is poorly adapted to existence outside the body of a host, is quickly killed by drying, and does not long survive even under favorable conditions.

It has been shown by experiment that in lambs and kids the worms will develop to a stage approaching maturity in the intestine after infection brought about by the ingestion of the eggs of the pig *Ascaris* (Experiments Nos. 22 and 23).

In the experiments on the lamb and the kid there can be no doubt that the partially developed worms found in the intestine came from the eggs that were fed to those animals. Obviously their infection could not reasonably be explained under the rat and mouse theory nor is it reasonable to suppose that they served as their own intermediate hosts and then swallowed their own feces containing larvæ that had been eliminated after passing through the lungs and intestine. The latter possibility, difficult to exclude in the case of pigs, is not one demanding serious consideration in the present instances, especially in view of the fact that the lamb and the kid were sucklings only a few days old when used in the experiments. Furthermore, the facts that sheep and goats are very unusual hosts of *Ascaris* and that in these experiments the parasites were found to be present in considerable numbers, in the case of the kid in enormous numbers, are facts of such a nature that the only possible conclusion is that the animals became infected from the eggs fed to them and that the larvæ after migrating from the intestine to the lungs and back again into the intestine settled down in the intestine and continued their development toward maturity. It appears, therefore, justifiable to conclude, in the light of all the available evidence, that man and pig become infected with *Ascaris* as a result of swallowing the eggs of the parasite and not from swallowing larvæ that have already undergone partial development in rats or mice.

It is evident with respect to *Ascaris suum* and probably also *Ascaris lumbricoides*, in view of the probable identity of the pig *Ascaris* and the human *Ascaris*, that these parasites show different degrees of adaptation to different host animals. In some animals (rat, mouse, guinea pig, rabbit) they are able to pass through a portion of their development and reach a stage in which they are ready to settle down in the small intestine, but are not able to develop further and are eliminated in the feces; in other animals (sheep, goat) they can develop to a stage approaching maturity, and finally, in their usual hosts (pig, man), they are able not only to pass through the earlier stages of development which may occur in imperfectly adapted hosts, but to continue their growth to fertile maturity.

The growth of *Ascaris* larvæ after they have reached the intestine following their migration through the lungs appears to be rather slow. In experiments on human subjects Epstein (1892) found that *Ascaris* eggs appeared in the feces 86 days after feeding *Ascaris lumbricoides* eggs. As the feces were also examined 12 days prior to the examination at which the eggs were first found, the worms in these cases, therefore, began producing eggs from 74 to 86 days after infection, so that at least about 2½ months were required for the full development of the parasites after infection. In our experiment with the lamb the worms were still considerably short of their adult size 103 days after infection, but, no doubt, their growth had been retarded by the fact that they were in an abnormal host. We have observed full-grown *Ascaris* in a pig 11 weeks old, so that it is evident that the parasites may attain maturity in pigs within 2½ months after infection. We may therefore conclude that *Ascaris*, both in human beings and in pigs, may reach maturity as early as 2½ months after infection.

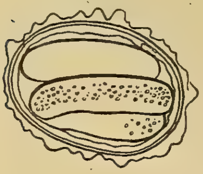

FIG. 1.—*Ascaris suum.* Egg containing fully developed embryo. Magnified 375 times.

DESCRIPTION OF LARVAL STAGES.

The newly hatched larvæ vary somewhat in size, commonly between 0.2 and 0.3 mm. in length. The specimen figured (figure 2) measured 0.22 mm. in length, 0.013 mm. in maximum thickness, esophagus 0.09 mm. in length, distance of excretory pore from anterior end of body 0.05 mm., and distance of anus from the tip of the tail 0.04 mm. The diameter of the body is nearly uniform throughout, head rounded, tail conical. On the anterior aspect of the head is a small, rounded knob, the so-called "tooth" of the *Ascaris* larva. This knob, according to Stiles (1891), is composed of three parts, corresponding to the lips of the adult *Ascaris*. In living specimens the outlines of the esophagus except posteriorly can not ordinarily be distinguished and the nerve ring is not apparent. This portion of the body is very clear, and free from color or conspicuous granules. The intestinal cells contain numerous small, yellowish-brown granules. The genital primordium is not evident in living specimens.

Before hatching, the larva (figure 1) is inclosed in a close-fitting, delicate cuticular sheath (shown in figure 2). When the larvæ are artificially expelled from the eggs (by applying pressure) they retain the sheath or in some cases cast it off as they emerge from the eggshell. At the anterior end the sheath is supplied with a crown of minute papillæ, apparently 6 in number. Under normal conditions it may be presumed that the larva undergoes its first molt at the time of hatching or shortly afterwards, following which at least another molt apparently occurs before the larva reaches the stage at which it migrates from the lungs to the intestine.

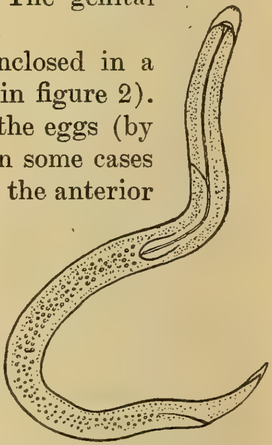

FIG. 2.—*Ascaris suum.* Newly hatched larva inclosed in cuticular sheath. Magnified 375 times.

The larvæ in the lungs reach a length of 5 to 10 times that of the newly hatched larvæ. The specimen shown (figure 3) is from the lungs of a rabbit 10 days after infection. It measures in length 1.43 mm., in maximum thickness 0.065 mm., length of esophagus 0.23 mm., distance of nerve ring from anterior end of body 0.11 mm., distance of excretory pore from anterior end of body 0.12 mm., distance of anus from tip of tail 0.08 mm., and distance of genital primordium from tip of tail 0.48 mm. The body is of nearly uniform diameter throughout, attenuated slightly from the base of the esophagus forward, and gradually from the beginning of the posterior third of the body backward, diminishing to about half its maximum diameter in the anal region; tail conical. Along each lateral line is a well-marked membrane (shown in cross section in figure 6). The mouth is small, pharynx very short, the esophagus beginning almost immediately back of the mouth; lips not conspicuous, the knoblike process on the anterior aspect of the head characterizing the newly hatched larva being no longer present. Just in front of the bulbous posterior end of the esophagus, sometimes on the right side, sometimes on the left side, is the large nucleus of a cervical gland. The genital primordium is small, not more than 0.015 mm. in diameter, oval in shape, consisting of a very few cells, situated on the ventral side of the intestine some distance posterior of the middle of the body.

In the living worm the esophageal region is clear and transparent, the intestinal region yellowish-brown through the presence of numerous granules of this color in the intestinal cells (figure 4).

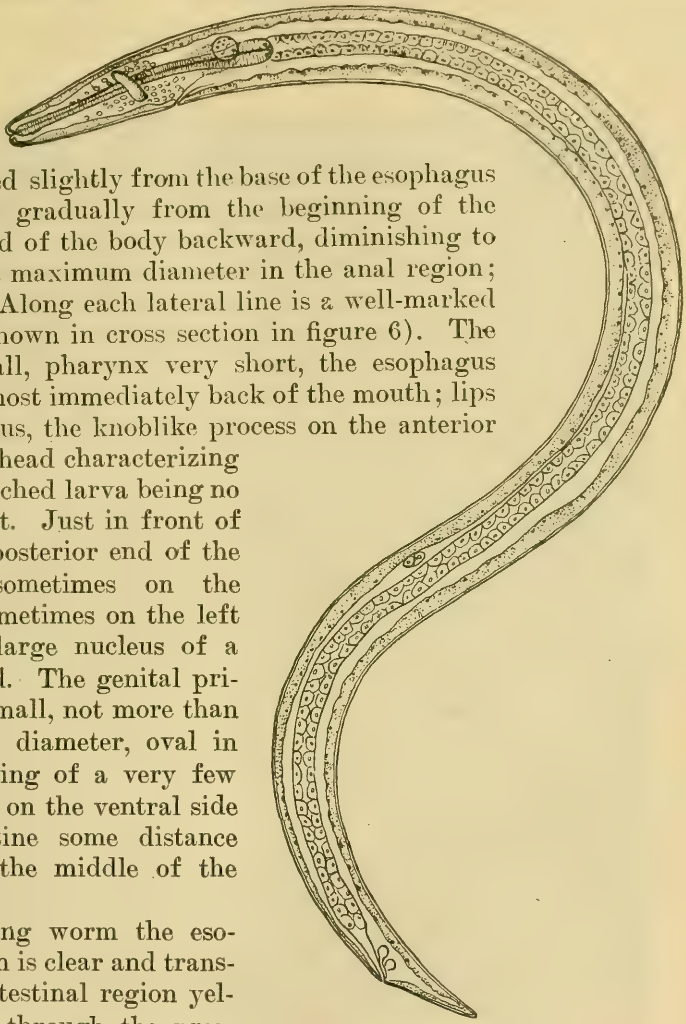

FIG. 3.—*Ascaris suum.* Larva from lung of rabbit 10 days after infection. Slightly flattened by pressure of cover glass. Magnified 150 times.

RELATION OF HOST TO SIZE OF DEVELOPING LARVÆ.

Parasites that are able to live in more than one species of host animal frequently exhibit differences of size in different species of animals. A good example is the gapeworm (*Syngamus trachealis*), with which young chickens can readily be infected by feeding the eggs of gapeworms taken from turkeys. In turkeys full-grown gapeworms commonly reach a length of 25 to 40 mm., but in chickens infected with material from turkeys the egg-producing adult rarely exceeds 15 to 20 mm. in length.

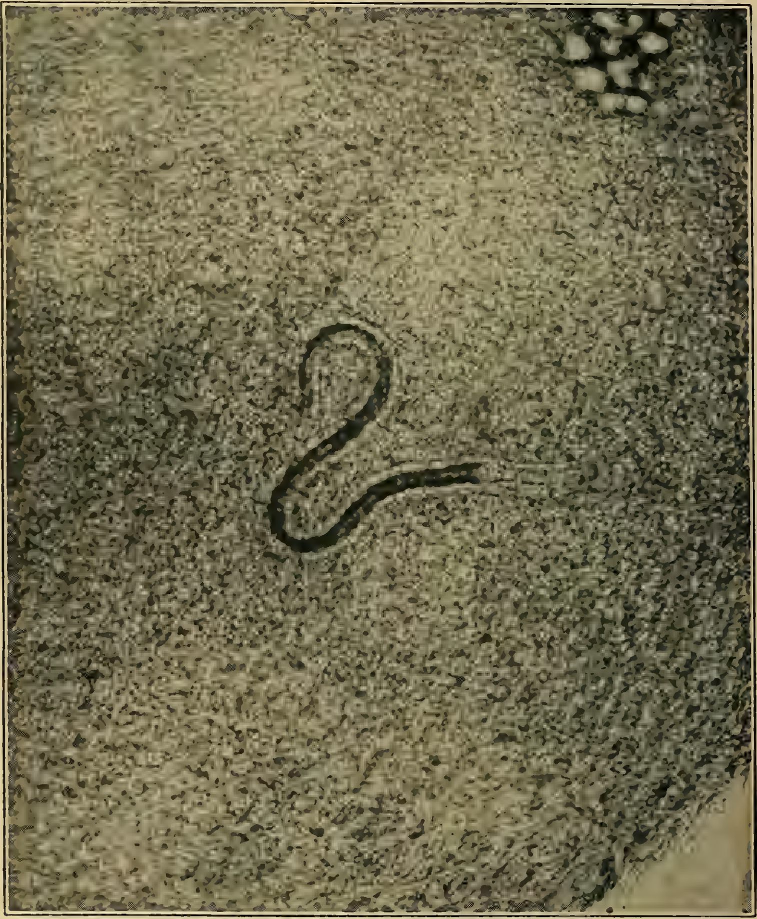

FIG. 4.—*Ascaris suum.* Larva in liver of mouse 10 days after infection. Photomicrograph of living specimen. Magnified.

In the case of migrating *Ascaris* larvæ differences of size are noticeable in different species of host animals, if a comparison is made of larvæ taken from different animals at corresponding times following infection. The following table has been compiled from the results of experiments on mice, guinea pigs, and rabbits:

Size of Ascaris larvæ in different host animals.

In mice.			In guinea pigs.			In rabbits.		
Age.	Location.	Length.	Age.	Location.	Length.	Age.	Location.	Length.
Days.		*Mm.*	*Days.*		*Mm.*	*Days.*		*Mm.*
5	Liver	0.28–0.34	4	Lungs	0.31–0.45	3	Liver	0.19–0.24
6	Lungs	.34– .4	5	do	.35– .83	5	do	.23– .45
7	do	.29– .6	5	Pharynx	.5 – .98	5	Lungs	.23– .48
9	do	.56– .86	6	Lungs	.35– .69	8	do	.33– .73
9	Large intestine.	.38– .46	6	do	.53– .9	8	Trachea	.75
10	Lungs	.6 –1.12	6	do	.63– .83	8	Esophagus	.99–1.33
10	Small intestine.	.83–1	6	Trachea	.71–1.13	8	Stomach	.6
10	Large intestine.	.75–1.45	6	Pharynx	.9	10	Lungs	.9 –1.8
			6	do	.8 –1.02	10	Stomach	1.5 –1.75
			7	Lungs	.65			

Although there is considerable variation in the size of larvæ taken from the same species of animal, from the same organ, the same number of days after infection, it is evident that there is a general increase in size with the lapse of time and with the progress of the larvæ through the liver, lungs, trachea, and into the alimentary tract; and furthermore, although differences in size between the larvæ from mice and guinea pigs, respectively, are not conspicuous, there appears to be a tendency for the larvæ to grow to a larger size in a corresponding time in rabbits than in either mice or guinea pigs. They seem to grow still larger in pigs in the same length of time. Measurements were made of 13 larvæ from the trachea of a pig that died 7 days after infection. This varied from 0.67 to 1.33 mm. in length, 8 of them being more than 1 mm. and the average close to 1.1 mm. These sizes correspond very well to those of larvæ taken from the esophagus of a rabbit 8 days after infection. The data that have been obtained as to the sizes reached by *Ascaris* larvæ in different species of host animals in a given period of time after infection are not sufficient to allow definite conclusions to be drawn, but the larvæ seem to grow more rapidly and to a larger size during their migrations in large animals than in small ones.

LESIONS ASSOCIATED WITH MIGRATING LARVÆ.

The principal organs that show pathological changes as a result of the invasion of *Ascaris* larvæ are the liver and lungs.

In the liver there is at first a capillary congestion, and hemorrhage by diapedesis; sometimes petechial or ecchymotic areas of inflammation are evident on the surface of the liver which later may become focal areas of necrosis. Commonly, however, as the larvæ leave the liver the congestion subsides. In our most severe cases, such as in the experiment (No. 23) on the kid, the inflammation was very extensive, the liver engorged with blood, bleeding freely when cut but cutting with difficulty, indicating a beginning induration.

The lesions in the lungs are more striking macroscopically than those in the liver. In our mildest cases there were small bright-red hemorrhagic spots, in which the larvæ usually could be discovered without difficulty. As a rule the lungs were more or less edematous. The small bright-red petechial hemorrhages and edema are very characteristic of *Ascaris* invasion and differentiate it from other conditions that are likely to be seen in the lungs of pigs. In more severe cases there were ecchymotic patches of considerable size, giving the lung a spotted appearance. In still more severe cases an entire lobe of the lung was involved, and in the worst cases both lungs were greatly swollen, edematous, intensely hemorrhagic, the color of liver, and extensively hepatized. Microscopically the pathological picture varied from that of an acute lobular pneumonia in which the areas of inflammation centered around the bronchioles to lobar pneumonia in the stage of red hepatization. The accompanying photomicrograph (figure 5) shows a section of the lung of a mouse with a larva in situ 7 days after ingestion of *Ascaris suum* eggs. In portions of the section will be noted areas of consolidation,

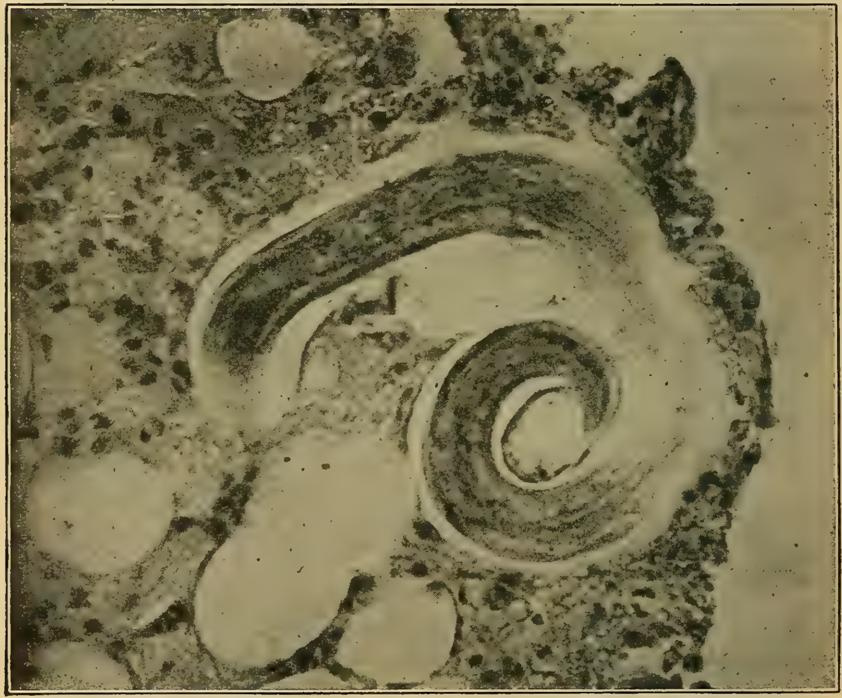

FIG. 5.—*Ascaris suum*. Larva in section of lung of mouse 1 week after infection. Photomicrograph. Highly magnified.

the air sacs being almost entirely filled in with the serosanguineous exudate. Extensive immigration of leucocytes and round-cell infiltration characteristic of acute inflammation are well marked. In other portions of the section the alveoli are enlarged, indicating a compensatory emphysema. Similar appearances are shown in figure 6, a photomicrograph of a portion of the lung of a pig one week after the ingestion of *Ascaris suum* eggs.

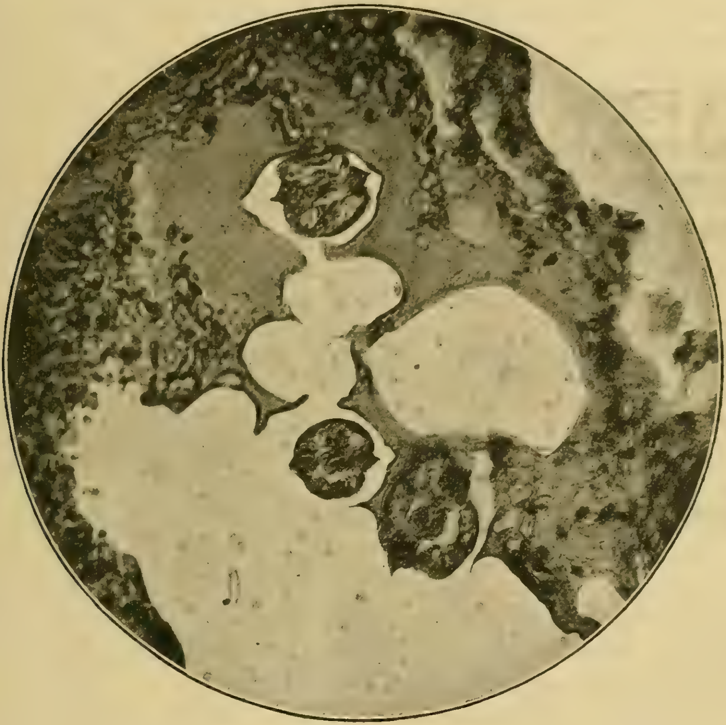

Fig. 6.—*Ascaris suum.* Larvæ in cross section in portion of lung of pig 1 week after infection. Photomicrograph. Highly magnified.

DEATH OF MIGRATING LARVÆ.

It is a general rule among animals that in species in which large numbers of young are produced the chances are slight that any given individual will reach maturity. In the case of *Ascaris*, which produces eggs in enormous numbers, there is a great loss of life among the parasites not only in the death of the eggs that do not reach a suitable host, but also in the failure of some eggs to hatch after they are swallowed, in the prompt elimination of such eggs and many newly hatched larvæ in the feces, and in the death of some of the larvæ in the course of their migrations through the body. Finally a further loss occurs in the elimination of larvæ in the feces after they have returned to the intestine following their migrations through the lungs. There is thus a great waste of life all along the line in the development of *Ascaris* that is offset only by the abundant fertility of the parasite.

We have repeatedly made observations showing that *Ascaris* larvæ may die in the course of their migrations through the body. That larvæ die in the liver is evident from the finding of dead and degenerated larvæ in the liver of a mouse which was killed 296 days after it had been fed *Ascaris suum* eggs. There was a small encapsulated tumor near the margin of the liver, containing a caseous material and several dead and degenerated *Ascaris* larvæ. On several occasions dead and more or less degenerated larvæ have been found in the lungs, for example in a rabbit 86 days after infection and in a pig 65 days after infection. It is quite probable that the larvæ that migrate to the spleen, thyroid, and other organs outside the usual path of migration ultimately die and become encysted and absorbed or perhaps in some cases stimulate the surrounding tissues to other reactions. In this connection the observations made by Gaylord and Marsh (1914) are of interest. It was observed that dogs fed on sediment from fishponds developed a thyroid hyperplasia and that in the thyroids of such animals there were sometimes found larval nematodes (*Agamonematodum gaylordi* Ransom). It appears quite possible that these larvæ were the young of some nematode occurring in the fish, and that ingested by the dogs they underwent migrations somewhat similar to those of *Ascaris* larvæ, some of them finally coming to rest in the thyroid. The etiological relation of these nematodes to the hyperplastic growths of the thyroid observed by Gaylord and Marsh is problematic. A somewhat similar association of dead nematode larvæ and other parasites with various sorts of neoplasms has been noted by different observers. No evidence has yet been obtained that the death of migrating *Ascaris* larvæ in the tissues of the host is followed by any serious consequences.

RELATION OF AGE TO ASCARIS INFESTATION.

It is a well-known fact that among human beings children are more commonly infested with *Ascaris* than adults. This difference is perhaps most noticeable in localities where the parasite is comparatively rare. In other places, where a large percentage of the population are carriers of *Ascaris* the fact that the parasite is of more frequent occurrence among children is less striking, but nevertheless unless practically the entire population harbor the parasites there is a more or less distinctly greater frequency in infestation among the younger individuals than among the older. For example, in the Philippines, Garcia (1917) from fecal examinations of 1,603 persons of various ages found the highest percentage of infestation among persons in the first decade of life, less among those in the second and third decades, and still less among those in the fourth to seventh decades. The average percentage was 27.8 and the per cent by ages was as follows:

Percentage of persons infested with Ascaris according to age (decade of life).

Decade of life.	Persons examined.	Infested.	Decade of life.	Persons examined.	Infested.
	Number.	*Per cent.*		*Number.*	*Per cent.*
First	98	42.9	Fourth	241	26.8
Second	355	33.5	Fifth	164	25.6
Third	615	33.5	Sixth and seventh	129	25.6

The greater frequency of *Ascaris* among children might be explained in two ways: First, their habits are such that they are more exposed to infection than older persons; second, children are more susceptible to infection than older persons. In the case of pigs there is no evident difference in the amount of exposure to infection between young and old animals except that the older pigs during their lifetime have had greater opportunities of becoming infected than younger pigs because they have lived longer, so that if equally susceptible at all ages older pigs should be more commonly and more heavily infested than younger pigs. As a matter of fact, however, there is a greater frequency of infestation among young than among old pigs, and they harbor more parasites than the older animals, so that it appears that young animals are more susceptible than older ones. The following table is based upon a post-mortem examination of the intestines of 2,583 hogs of various ages slaughtered for market at Chicago abattoirs. The examinations were made and the ages of the animals estimated by Dr. H. B. Raffensperger. Dr. Raffensperger sorted the worms found into three groups according to size, small (up to 2½ inches long), medium (slender worms between 2½ and 5 inches long), and adult (plump worms 5 inches or more long). Great care was taken in examining the contents of the intestine to obtain every worm possible, but it is quite certain that some of the small worms were overlooked, so that the figures are less accurate for the small than for the medium and adult worms.

Results of post-mortem examinations of hogs of various ages for the presence of Ascaris suum in the intestine.

Item.	Age in months—						
	1 to 2½	2½ to 5	5 to 7	7 to 12	12 to 18	18 to 48	All ages.
Hogs examined ... number	55	584	363	699	626	256	2,583
Hogs infested ... do.	19	304	158	299	238	91	1,109
per cent	34.5	52.1	43.6	42.8	38	35.5	[1] 41.1
Total worms found ... number	82	1,936	684	1,489	1,243	541	5,975
Average worms per hog ... do.	1.6	3.3	1.9	2.1	2	2.1	[1] 2.1
Average worms per hog infested ... do.	4.5	6.4	4.3	5	5.2	6	[1] 5.2
Small worms [2] ... per cent	....	4.2	4.2	4.2	5.6	.8	[1] 3.1
Medium worms [3] ... do.	97.6	49.2	33.2	35.9	39.4	31.4	[1] 47.8
Adult worms [4] ... do.	2.4	46.5	62.7	60	54.9	67.8	[1] 49.1

[1] Weighted average or per cent.
[2] Not more than 2½ inches long.
[3] Slender worms intermediate in size between small and adult worms.
[4] Plump worms 5 inches or more long.

From the table it appears that the highest percentage of intestinal infestation with *Ascaris* is found in pigs between the ages of 2½ and 5 months, about half of which are infested. Beyond this age the percentage of infestation gradually decreases until among old hogs over 1½ years of age only about one in three is infested.

The figures relating to the numbers of worms of different sizes found are of interest with reference to the question of the age at which pigs are most susceptible to infection. We know that about 2½ months is required for *Ascaris* to reach maturity after the eggs have been ingested. We should therefore expect few if any adult worms among the pigs of the first age class (1 to 2½ months), and this is the case, less than 3 per cent of the worms present in these young pigs being adult worms. In pigs 2½ to 5 months old on the other hand nearly one-half of the worms are mature, in pigs of the next class (5 to 7 months) nearly two-thirds of the worms are mature, then there is a slight decrease in the proportion of mature worms in the next two age groups, the proportion again increasing in pigs 1½ to 4 years old in which over two-thirds of the worms are mature.

It is not known how long an individual *Ascaris* may live, but in view of the rather large size of the worm and its slow growth to maturity it is probable that it is long-lived; quite likely it may live a year and perhaps much longer. Thus, infested pigs a year or more old may as a rule have acquired their worms while still very young, no additional infection having occurred after the first few months of life. The table, however, shows that pigs continue to be susceptible to infection as they grow older. In fact, the percentage of small worms among pigs 12 to 18 months old is higher than among the pigs of the younger groups and even among the oldest pigs (1½ to 4 years old) small worms were occasionally encountered, indicating recent infection, a considerable number (nearly one-third) of the worms present being of medium size, indicating comparatively recent infection (probably within 2½ months). The table nevertheless seems to show that pigs less than 5 months old are considerably more susceptible to infection than older pigs.

Without attempting further analysis of the figures given in the table, we may conclude that among the pigs coming to the Chicago market slightly more than half of those less than 5 months old have been found to be infested with *Ascaris*, and that among older pigs the frequency of infestation progressively decreased with age until among pigs 1½ years or more old only about one animal in three was infested. Further, the pigs less than 5 months old showed a greater average number of worms than older pigs, although as a natural result of the slow growth of the parasites they showed relatively fewer adult worms. Finally, it may be concluded that young pigs are considerably more susceptible to infection than older pigs, but that this susceptibility, although diminishing, does not become lost with advancing age.

Whether the lessened susceptibility of pigs to *Ascaris* infection as they become older is the result of immunity following previous infections or of increased resistance to infection which comes with advancing age is perhaps not altogether certain, but it is likely that age is the determining factor rather than the establishing of an immunity in consequence of an earlier infection. If an immunity is established as a result of infection it is not immediately established, inasmuch as an experiment on a kid (Experiment No. 23) has shown that two infections may occur with an interval of 17 days between. Furthermore, natural cases have been observed in which there were adults and smaller worms in the intestine and at the same time larval worms in large numbers in the lungs. That age is sometimes an important factor in the occurrence of parasitic infection is indicated by experiments by the senior writer with gapeworms (*Syngamus trachealis*) which have shown that chickens become less susceptible to infection as they grow older, adult chickens rarely harboring the parasites. Various observers have noted in the case of other parasites that young animals are more susceptible to infection than older animals, and it is evident that age often has a great deal to do with susceptibility to invasions by parasites. On the other hand, in the case of some parasites and some species of host animals, no immunity develops with increasing age. For example, although there is a great reduction in the susceptibility of chickens to infection with the gapeworm as they become older, there is no marked difference in the susceptibility of turkeys of different ages to infection with the same parasite.

The question of the production of immunity to *Ascaris* infection as the result of earlier infections requires further investigation. Our present knowledge, however, indicates that as pigs grow older they become less susceptible to *Ascaris* infection, not because they have been immunized by earlier infections, but because with advancing age they become more resistant to infection.

ASCARIS PNEUMONIA.

As first shown by Stewart (1916a), the invasion of the lungs by *Ascaris* larvæ may cause a serious, sometimes fatal, pneumonia. Rats which had been fed *Ascaris* eggs became ill with a pneumonia four to six days afterwards and on post-mortem examination numerous *Ascaris* larvæ were found in the lungs. In later papers Stewart also notes the occurrence of pneumonia in mice and pigs following the administration of *Ascaris* eggs.

The present writers have also observed the common occurrence of pneumonia in animals that have been fed with *Ascaris* eggs, reference to which has already been made in a former paper (Ransom and Foster, 1917). The symptoms of pneumonia appear within a few days, usually about a week, after the ingestion of the eggs, and the animal may die within a day or two after the first symptoms are observed.

Among pigs very young animals seem more liable to develop serious cases of *Ascaris* pneumonia than older animals. Our worst cases among pigs have been in sucklings.

In view of the results of experiments on various animals (rat, mouse, guinea pig, rabbit, pig, goat), it seems quite probable that *Ascaris* larvæ are capable of causing pneumonia in human beings, particularly in children. Evidence that they may cause lung trouble in human beings is found in the fact that Mosler (in Leuckart, 1867) observed the occurrence of dyspnea among children to whom he had given *Ascaris* eggs a few days before. As Stewart has very properly remarked, experiments in infecting children with *Ascaris*, such as those carried out by Mosler and by Epstein (1892), are highly reprehensible. Even though Mosler and Epstein were unaware of the fact that *Ascaris* larvæ may cause a dangerous and possibly fatal affection of the lungs, their use of children as experimental animals can not be justified. Lutz (1888) has recorded the occurrence of symptoms in a young man who volunteered as a subject for experiments with *Ascaris* that were in all probability related to the invasion of the lungs by the larvæ, though the fact that the larvæ migrate through the lungs was, of course, not known to Lutz.

Lung affections, including the condition commonly known as "thumps," are of very common occurrence among young pigs, resulting in numerous deaths. These are undoubtedly often caused by *Ascaris* infection, and, in fact, numerous natural cases corresponding exactly to cases of experimental infection, have been observed by Dr. H. B. Raffensperger, of this bureau, in the course of investigations carried out by him under direction of the Zoological Division in various localities in the field. *Ascaris* is a common parasite and the soil in places occupied by pigs is liable to be heavily laden with the eggs of the parasite. There is consequently plenty of opportunity for newborn pigs to become infected. Dirt from the pigpen adheres to the skin of the sow, and the young pig in suckling swallows not only its mother's milk but also *Ascaris* eggs from the dirty teats. In addition, many eggs are likely to be picked up by the young pig in rooting about in the soil of the pigpen. It would therefore seem that greater care of the sow and the pigpen with reference to cleanliness, by reducing the chances of infection to which young pigs are exposed, would go far toward reducing the losses from pneumonia.

LONGEVITY OF LARVÆ OUTSIDE THE HOST.

Stewart (1916a) noted that the newly hatched larvæ eliminated in the feces of rats recently fed the eggs of *Ascaris lumbricoides* might survive for three days. He found, further, that larvæ that had passed through the lungs and reached the large intestine of mice if placed in tap water were alive and active at the end of two hours, but were dead at the end of 24 hours. Larvæ from the lungs of a rabbit that died 10 days after feeding with the eggs of *Ascaris suum* have been kept alive in physiological salt solution by the writers for 13 days (Experiment No. 16).

The survival of larvæ as long as 13 days after their removal from the host would seem to offer some support to Stewart's rat and mouse theory, but the fact that they are so slightly resistant to unfavorable conditions, such as dryness, and as observed by Stewart may not live as long as 24 hours in tap water, is evidence very much against Stewart's suggestion as to the spread of *Ascaris* larvæ from rats and mice to human beings or pigs. It is known that adults removed from the intestine of their host can be kept alive for considerable periods of time. For example, Hall (1917) found that they may survive removal from their host as long as 26 days if kept in Kronecker's solution. Many species of parasitic nematodes can thus be kept alive with careful handling after removal from their host. The survival of *Ascaris* larvæ for a time if kept in physiological salt solution after they have been removed from a host animal is therefore a phenomenon not unusual among parasitic nematodes, and can not be considered as indicating the probability, under natural conditions, of the passage of the larvæ from one host to another and the resultant infection of the latter.

NATURAL OCCURRENCE OF ASCARIS IN SHEEP.

Sheep are occasionally found to be infested with *Ascaris*. Rudolphi (1819, p. 49) mentions under the name of *Ascaris ovis* a specimen in the collections of the Vienna Museum. Diesing (1851) and von Drasche (1883) give descriptions of this specimen, and the latter also describes two badly preserved specimens of *Ascaris* found in a sheep by Koebel. Copeman (1842) found 25 ascarids in a lamb. Neumann (1884) found several specimens of *Ascaris* in sheep. In the collections of the Bureau of Animal Industry are specimens of *Ascaris* collected from sheep at Brookings, S. Dak., Blairsville, Pa., and Bethesda, Md. Apparently in no case has a fully developed female *Ascaris* containing well-formed eggs been found in sheep.

The worms have always been apparently underdeveloped, which has led some to hold the opinion that the sheep ascarids which resemble *Ascaris lumbricoides* are imperfectly grown worms of this species, or of *Ascaris suum* if the pig *Ascaris* is considered distinct from the human *Ascaris*. In view of the experience of the writers in artificially infecting a lamb by feeding the eggs of the pig *Ascaris* it would appear that the common opinion as to the identity of the sheep *Ascaris* is correct. As further evidence of the ability of species of *Ascaris* to undergo at least a partial development in the intestine of a strange host may be cited the results of our experiment in feeding *Ascaris suum* eggs to a young goat, and it may also be noted that Jammes and Martin (1906) record the development of *Ascaris vitulorum* in the human intestine to a length of 8 mm. One of these writers swallowed *A. vitulorum* eggs and recovered the young worms in his feces 25 days later.

LIFE HISTORY OF RELATED NEMATODES.

The migration of the larvæ of intestinal parasites through the lungs of the host before they finally settle down in the intestine is not peculiar to *Ascaris*. It has been shown by Looss and others that the larvæ of hookworms and of *Strongyloides*, after entering the host through the skin, migrate to the lungs through the heart by way of the lymphatics and blood vessels, and then pass up the trachea and down the esophagus, finally reaching the intestine.

The senior writer has observed the larvæ of *Hæmonchus contortus* (stomach worm of ruminants) in the lung of a guinea pig killed 48 hours after it had been fed a culture of the larvæ, which indicates that they are able to migrate from the alimentary tract to the lungs and perhaps do so normally in their life cycle in their usual hosts, sheep, cattle, etc.

In view of the fact that the larvæ of forms belonging to diverse genera, *Ancylostoma*, *Strongyloides*, *Ascaris*, and, perhaps, *Hæmonchus*, regularly migrate through the lungs before establishing themselves in the intestine, it is quite likely that the phenomenon is one of common occurrence in the life cycle of parasitic nematodes. It is to be expected, certainly, that forms closely related to *Ascaris lumbricoides* will act similarly with respect to the migration of the larvæ through the lungs. Stewart (1918a, p. 194) found the larvæ of *Belascaris marginata* in the liver of mice 1 to 3 days after they had been fed eggs of this parasite. The present writers have fed the eggs of *Belascaris marginata* to rats and 5 days later have found the larvæ in the lungs. The lungs showed petechial hemorrhages similar to those observed in the lungs of animals invaded by the larvæ of *Ascaris lumbricoides* or *Ascaris suum* (Experiment No. 8).

A python that died at the National Zoological Park, Washington, D. C., was infested with a species of parasite corresponding to descriptions of *Ascaris anoura.* This nematode apparently passes through the lungs in its life cycle, inasmuch as in addition to 28 adult worms 115 to 160 mm. long, in the intestine of the python referred to, there were found in the lungs 65 young worms resembling in their structural details the adults from the intestine. These young worms varied in length from 18 to 38 mm., and if of the same species as the intestinal worms, as they appeared to be, it is evident that the larvæ of this species can develop much further in the lungs than the larvæ of *Ascaris lumbricoides.*

Considering the migration of the larvæ of *Ascaris* and other intestinal nematodes through the lungs, it might be argued from an evolutionary standpoint that parasitism of the lungs by nematodes is a more primitive condition than parasitism of the alimentary tract, and that only as the worms acquired a complete immunity to the effects of the digestive juices of the host did they move on into the stomach or intestines.

DETAILS OF EXPERIMENTS WITH ASCARIS.

The following records of the writers' experiments do not cover all the experiments that were made. A considerable number are omitted, as they add little to what is shown by those selected, so far as concerns the infection of experiment animals and the migrations of the larvæ in the body of the host. Numerous experiments have also been made relating to the hatching of *Ascaris* eggs in vitro, action of chemical reagents on the eggs, incubation of the eggs, etc., but the details of these experiments will not be given in the present bulletin.

Experiment No. 1.

January 15, 1917: Seven white mice fed with bread liberally soaked with a culture of eggs of *Ascaris suum.*

January 19, 1917: Second feeding.

January 24, 1917: Third feeding.

January 27, 1917: Killed two of the mice, 12 days after the first feeding, 8 days after the second, 3 days after the third. Post-mortem examination showed in one of the mice 21 larvæ in one-half of the lungs, 1 larva in the small intestine, and 1 larva in the liver. In the other, 56 larvæ in one-half of the lungs, 1 larva in the esophagus, 2 larvæ in the trachea, and none in the small intestine.

February 3, 1917: Two mice died, 19 days after the first feeding, 15 days after the second, 10 days after the third. One was examined and 1 larva found in the small intestine. The other mouse was not examined. Three of the mice originally included in this experiment either escaped from the cage or died and were destroyed without post-mortem examination. The feces remaining in the cage at the close of the experiment were examined for larvæ but none were found.

Experiment No. 2.

February 28, 1917: Fed 5 mice with eggs of *Ascaris suum* on bread.

March 3, 1917: Second feeding.

March 10, 1917: One mouse died with symptoms of pneumonia; no postmortem.

March 14, 1917: Two more mice died from pneumonia, 14 days after the first feeding, 11 days after the second. The post-mortem showed a heavy invasion of the lungs in both mice. In one of the mice no larvæ were found in the liver or small intestine, 5 larvæ in the cecum; in the other, 2 larvæ in the liver, 36 in the small intestine, 4 in the cecum.

The larvæ in the lungs were of two rather distinct sizes evidently corresponding to the different dates of infection. The larger size varied from 0.53 to 0.88 mm., the smaller from 0.28 to 0.33 mm. in length.

March 23, 1917: Examined feces of remaining mice for larvæ. Negative.

March 26, 1917: Killed fourth mouse 26 days after first feeding, 23 days after second feeding. Post-mortem: Lungs, 15 larvæ 1.3 to 1.4 mm.; spleen, 2 larvæ 0.8 mm.; thyroid, 1 larva 0.7 mm.; liver, 2 larvæ 0.8, 0.9 mm.; small intestine, 1 larva 1.2 mm.; cecum, 7 larvæ 1.6–1.9 mm.

March 28, 1917: Examined feces of fifth mouse. Negative.

April 21, 1917: Killed fifth mouse. Negative.

Experiment No. 3.

April 27, 1917: Fed 6 mice at 11 a. m. *Ascaris suum* eggs on bread.

April 28, 1917: Killed 2 mice 28 hours after first placing food before them. One negative; in small intestine of the other 1 *Ascaris* egg with shell intact, in stomach 4 *Ascaris* eggs containing living embryos.

May 2, 1917: Killed third mouse 5 days after feeding. Several larvæ in liver, 0.4 to 0.55 mm. long; length of esophagus 0.1 to 0.3 mm., distance from anus to tip of tail 0.07 mm., greatest width 0.02 mm. Spleen, lungs, heart, kidney, stomach, small intestine, cecum, negative.

May 5, 1917: Killed fourth mouse 8 days after feeding. Larvæ in liver only, 0.4 mm. long.

May 10, 1917: Killed fifth mouse 13 days after feeding. Larvæ in liver, lungs, under peritoneum in various parts of abdominal cavity, in feces. Larvæ in feces were 1.2 to 1.75 mm. long. Length of esophagus 0.18 to 0.23 mm. Anus to tip of tail 0.1 mm. Larvæ in lungs 1.7 mm. long. Length of esophagus 0.24 mm. Anus to tip of tail 0.08 mm. Nerve ring 0.11 mm., excretory pore 0.14 mm. from anterior end of body. Maximum width of body 0.06 mm.

February 12, 1918: Killed sixth mouse 9½ months after feeding. Negative except for a few small black spots on the lungs, like the remains of old hemorrhages.

Experiment No. 4.

February 26, 1917: Fed 8 mice *Ascaris suum* eggs on bread.

March 2, 1917: First mouse died 4 days after feeding. Negative.

March 17, 1917: Killed second mouse 19 days after feeding. Seven larvæ in liver, 8 in spleen, none in other organs.

March 26, 1917: Killed third mouse 28 days after feeding. Negative.

April 19, 1917: Killed fourth mouse 52 days after feeding. Negative.

July 5, 1917: Killed fifth mouse 129 days after feeding. Negative.

November 10, 1917: Killed sixth mouse 257 days after feeding. Negative.

December 3, 1917: Killed seventh mouse 280 days after feeding. Negative.

December 19, 1917: Killed the last mouse 296 days after feeding. A small, encapsulated tumor, superficial, in liver near the margin contained degenerated larvæ and a waxy or caseous substance. No definite calcification.

Experiment No. 5.

June 23, 1917: Fed 12 white mice at 11 a. m. eggs of *Ascaris suum* on bread, after starving 24 hours.

June 25, 1917: Killed the first mouse 51 hours after feeding. In stomach 2 unhatched eggs; in small intestine a few unhatched eggs. Lungs and spleen negative. Liver heavily infested with larvæ 0.28 to 0.33 mm. long. In large intestine unhatched eggs containing viable embryos.

It is evident that within 51 hours large numbers of the larvæ have lodged in the liver, but apparently the lungs have not yet been invaded. It is interesting to note that a number of eggs still remain in various parts of the digestive tract and, apparently, are in the process of passing out, since they are found fairly numerous in the large intestine.

June 28, 1917: Killed second mouse 5 days after feeding. Liver heavily infested. Larvæ from the liver were kept alive in salt solution for 24 hours, but all died within 48 hours. Lungs, spleen, small and large intestines negative. Larvæ in liver measured 0.28 to 0.34 mm. in length.

June 29, 1917: Third mouse died of pneumonia 6 days after feeding. Intense congestion and hemorrhage by diapedesis. No larvæ in the liver, spleen, or intestines, but very numerous in the lungs. Larvæ in lungs measured 0.34 to 0.4 mm. in length.

June 30, 1917: Fourth and fifth mice died of pneumonia 7 days after feeding. Lungs heavily loaded with larvæ, 0.29 to 0.6 mm. in length. Other organs not examined.

July 2, 1917: Sixth mouse died from pneumonia 9 days after feeding. Lungs heavily infested with larvæ, 0.56 to 0.86 mm. in length. Liver heavily infested with larvæ, 0.56 to 0.86 mm. in length. Small intestine, 3 larvæ. Esophagus, numerous larvæ, 0.9 to 1.45 mm. in length. Spleen, 1 larva, 0.36 mm. long. Cecum, 4 larvæ, 0.38 to 0.46 mm. long.

July 3, 1917: Seventh mouse died 10 days after feeding. Lungs heavily infested; larvæ 0.6 to 1.12 mm. in length. Small intestine, numerous larvæ, 0.83 to 1 mm. in length. Large intestine, several larvæ, 0.75 to 1.45 mm. in length. Spleen negative.

Most of the larvæ remained actively motile in the tissues for 24 hours after the animal died, but all larvæ were apparently dead 48 hours after the death of the host.

July 5, 1917: Killed eighth mouse 12 days after feeding. Lungs heavily infested.

Of the 4 mice remaining 3 were lost track of and 1 was still alive June 5, 1918.

Experiment No. 6.

September 22, 1917: Fed 6 white mice with eggs of *Ascaris suum* on bread.

September 24, 1917: One mouse died 2 days after feeding. No larvæ in liver.

September 29, 1917: Second mouse died 7 days after feeding. Not examined.

October 4, 1917: Third mouse died from pneumonia 12 days after feeding. Numerous larvæ in lungs. Other organs not examined. Two mice born to one of the mice fed September 22.

October 5, 1917: Fourth mouse died 13 days after feeding. Not examined.

October 6, 1917: Two remaining mice died 14 days after feeding. Larvæ found in lungs.

October 9, 1917: The 2 mice born October 4 were examined and found free from infection.

Experiment No. 7.

November 4, 1917: A half-grown cat was fed many thousands of eggs of *Ascaris suum.*

November 12, 1917: Cat chloroformed and examined 8 days after feeding. Lungs, liver, spleen, small intestine, trachea, and pharynx examined and found negative.

Experiment No. 8.

August 21, 1916: Two rats were fed bread soaked in a culture of *Belascaris marginata* incubated for 33 days in weak formalin.

August 22, 1916: Feces of rats contained *Belascaris* eggs with unhatched motile embryos, and a few hatched dead embryos.

August 26, 1916: Killed one rat 5 days after feeding. Lung with hemorrhagic petechiæ. One active larva found. Other organs not thoroughly examined.

August 29, 1916: Killed second rat 8 days after feeding. Lungs with hemorrhagic petechiæ but a hurried examination failed to reveal worms.

Experiment No. 9.

October 11, 1917: Fed 6 guinea pigs with culture of *Ascaris suum*, each animal receiving two pipettes—about 2.4 cubic centimeters—of the culture. The animals were also allowed to eat oats over which a culture of *Ascaris* eggs had been poured.

October 16, 1917: Killed the first guinea pig 5 days after feeding. The postmortem showed numerous larvæ in the lungs, 1 larva in trachea, none in liver, spleen, esophagus, and small intestine.

October 17, 1917: Second guinea pig died 6 days after feeding. Lungs intensely hemorrhagic (color of beef liver). Larvæ very numerous in lungs; numerous in trachea. Esophagus, stomach, liver, spleen, small intestine all negative. The larvæ in the lungs varied in length from 0.35 to 0.69 mm., with esophagus 0.12 to 0.15 mm. in length. Those in the trachea were considerably larger, 0.71 to 1.13 mm. in length, 0.035 to 0.04 mm. in width, with esophagus 0.13 to 0.15 mm. long.

October 17, 1917: Third guinea pig died, 6 days after feeding. Lungs intensely hemorrhagic. Larvæ were very numerous in the lungs, numerous in the trachea, several in the pharynx, 2 in the esophagus. Liver, spleen, stomach, small intestine all negative. Large intestine not examined. The larvæ in the pharynx varied in length from 0.6 to 1.02 mm., the largest measuring 0.045 mm. in width, with esophagus 0.19 mm. long.

October 18, 1917: Fourth guinea pig died from pneumonia 7 days after feeding. Numerous larvæ in lungs, several in trachea, 2 in the stomach 0.49 and 0.78 mm. in length, both dead and degenerated, possibly from the action of the digestive juices. Small intestine, liver, thyroid, Fallopian tubes, pharynx, all negative. Esophagus not examined.

October 19, 1917: Fifth guinea pig died from pneumonia 8 days after feeding. Larvæ very numerous in lungs, numerous in trachea and pharynx, not found in esophagus, liver, thyroid, submaxillary glands, stomach, and small intestine.

October 19, 1917: Sixth guinea pig died from pneumonia 8 days after feeding. Larvæ very numerous in lungs, several in trachea and esophagus. Not found in liver, spleen, stomach, small intestine, uterus, or Fallopian tubes.

Experiment No. 10.

June 15, 1918: Fed 6 guinea pigs with eggs of *Ascaris suum* incubated since April 2.

June 19, 1918: Killed first guinea pig 4 days after feeding. Lungs intensely hemorrhagic. Numerous larvæ in lungs, also unhatched eggs. Larvæ in lungs measured 0.31 to 0.45 mm. in length. Liver, trachea, esophagus, negative. Other organs not examined. All the guinea pigs showed symptoms of pneumonia evidenced by dyspnea and abdominal breathing.

June 20, 1918: Guinea pig No. 2 died 5 days after feeding. Lungs intensely hemorrhagic, unhatched eggs in lungs. Larvæ in lungs, trachea, and pharynx. None in liver or small intestine. Other organs not examined. Measurements of larvæ in different organs as follows: Lungs, 0.35 to 0.83 mm. in length; trachea, 0.5 to 0.88 mm.; pharynx, 0.5 to 0.98 mm.

June 21, 1918: The 4 remaining guinea pigs died 6 days after feeding. Postmortem on third guinea pig showed pneumonia with red hepatization of the lungs; numerous larvæ in lungs, one in pharynx, none in trachea, liver, or spleen. Other organs not examined. Measurements of larvæ in different organs as follows: Lungs, 0.63 to 0.93 mm.; pharynx, 0.9 mm.

June 26, 1918: Fourth guinea pig examined (kept in refrigerator since death, June 21). Lungs hemorrhagic, containing numerous larvæ. Several larvæ in trachea; other organs not examined.

June 27, 1918: Fifth guinea pig examined (kept in refrigerator since death, June 21). Numerous larvæ in lungs, which were in a stage of red hepatization. Spleen and liver negative. Other organs not examined.

June 29, 1918: Sixth guinea pig examined (kept in refrigerator 8 days since death). Lungs heavily infested; several larvæ in trachea; larvæ in lungs and trachea, actively motile 8 days after death of host. Measurements of larvæ in different organs as follows: Trachea, 0.6 to 0.9 mm.; lungs, 0.53 to 0.9 mm.

The presence of unhatched eggs in the lungs of 2 of the guinea pigs may be explained by assuming that some of the eggs passed down the trachea instead of the esophagus, when the animals were being forcibly fed with a pipette. This explanation is strengthened by the fact that we have never seen unhatched eggs in the lungs of mice which were infested by being allowed to eat contaminated food without compulsion.

That *Ascaris* larvæ can live for some time after the death of the host is shown in this experiment in which larvæ in the lungs and trachea were seen to be actively motile 8 days after the host animal died. Apparently, however, no growth occurred during this period, since larvæ from the lungs of the guinea pig which was examined on the day of its death measured 0.63 to 0.93 mm. (maximum and minimum of 10 specimens), while larvæ from the lungs of the guinea pig which had been dead 8 days measured practically the same—0.53 to 0.9 mm. (9 specimens).

Experiment No. 11.

October 29, 1917: Fed 2 guinea pigs at 11 a. m. with about 3.6 cubic centimeters of a culture of eggs of *Ascaris suum* in weak formalin. Culture started September 1.

October 30, 1917: Killed 1 guinea pig at 3 p. m., 28 hours after feeding, bled from neck, catching blood in test tube. Centrifuged with an equal amount of 1 per cent sodium-citrate solution. No larvæ found.

October 31, 1917: Two days after feeding, second guinea pig etherized about 2 p. m. and when entirely anesthetized the abdomen was opened and blood drawn by a syringe directly from the portal vein, the blood being delivered into a test tube containing 5 cubic centimeters of a 5 per cent solution of acetic acid and centrifuged. The second specimen of the sediment taken for examination from the bottom of the tube contained two larvæ about 0.28 mm. long.

It appears from the experiment above that 48 hours after feeding cultures of *Ascaris* eggs, *Ascaris* larvæ may be found in the blood in sufficient numbers to be demonstrated in the portal circulation, but the results of a single experiment such as this can not be accepted as conclusive.

Experiment No. 12.

November 3, 1917: Fed 3 guinea pigs with culture of *Ascaris suum.*

November 5, 1917: Two days after feeding killed and examined blood of first guinea pig, keeping portal system and systemic system separate, using 3 per cent acetic acid, same technique as in previous experiment. Both liver and blood negative.

November 6, 1917: Three days after feeding killed and examined second guinea pig, drawing blood from pulmonary artery. One larva seen. Two larvæ in lungs; none in liver.

November 9, 1917: Third guinea pig died from pneumonia six days after feeding. Many larvæ in lungs, several in trachea, one in esophagus, one in small intestine, none in liver.

It appears from the above experiment that the larvæ after leaving the liver are carried by the systemic circulation to the heart and thence by the pulmonary artery to the lungs. In this experiment as early as three days after infection a few larvæ had already entered the lungs and as none were found in the liver it is possible that most of the larvæ were in the blood stream on the way to the lungs. The results of a single experiment such as this, however, can not be accepted as conclusive.

Experiment No. 13.

November 22, 1917: Three guinea pigs injected subcutaneously with *Ascaris suum* eggs.

November 30, 1917: Killed first guinea pig eight days after injection. Larva in lungs, 0.5 mm. long. Abscess at site of injection contains *Ascaris* eggs, the embryos dead and unhatched. Spleen, trachea, and esophagus negative; lungs with hemorrhagic spots.

December 4, 1917: Killed second guinea pig 11 days after injection. Larva in lungs, 1.5 mm. long; one anterior lobe of lung chocolate brown; a few hemorrhagic spots over the rest of the lungs. Spleen, trachea, and esophagus negative. Unhatched eggs containing vermiform embryos in abscess at site of injection.

December 4, 1917: Killed third guinea pig 11 days after injection. Lungs showing extensive inflammation and covered with dark hemorrhagic spots. Larvæ in lungs; one measured 1.3 mm. in length. Larvæ in trachea measuring 1.5 mm. Spleen and esophagus negative. Eggs in abscess under skin at site of injection. Some empty shells. Embryos in eggs dead.

The experiment of injecting *Ascaris* eggs beneath the skin was repeated, six guinea pigs being used. Similar results were obtained, the larvæ being found in each case in which the lungs were examined a week to 10 days after injection of the eggs.

Experiment No. 14.

December 3, 1917: Fed three rabbits (with pipette) heavy doses of a 2 per cent formalin culture of *Ascaris suum* eggs. Culture started October 22.

December 13, 1917: Ten days after feeding, one rabbit died. Lungs intensely hemorrhagic in the stage of red hepatization; extreme hemolysis. Blood thin and watery and would not coagulate after long standing. Thousands of larvæ throughout the lung tissue. Small pieces taken at random were always found swarming with worms. Larvæ were also numerous in the trachea, esophagus, lungs, and stomach. The small intestine, liver, and spleen were negative. Measurements of larvæ in different organs as follows: Lungs, 0.9 to 1.8 mm.; stomach, 1.45 to 1.75 mm.

February 27, 1918: Killed second rabbit 86 days after feeding. Two dead and encapsulated larvæ seen in the lungs; none in the liver, spleen, trachea, esophagus, or small intestine. Lungs showed a few petechiæ but otherwise were normal in appearance.

March 12, 1918: Third rabbit died from pneumonia (not verminous) 99 days after feeding. No larvæ seen in liver, lungs, trachea, esophagus, or spleen. Other organs not examined.

Experiment No. 15.

July 3, 1918: Fed 3 rabbits with eggs of *Ascaris suum* incubated since April 4, 1918.

July 6, 1918: Killed first rabbit 3 days after feeding. Numerous larvæ in liver, 1 in lungs, 1 in trachea. Spleen negative; other organs not examined. Parasites in liver, 0.2 to 0.25 mm. One in trachea measured 0.23 mm.

July 8, 1918: Killed second rabbit 5 days after feeding. Larvæ in liver and lungs. Spleen, trachea, and esophagus negative. Other organs not examined. Larvæ in liver (4 specimens), 0.23 to 0.45 mm. Larvæ in lung (9 specimens), 0.23 to 0.48 mm.

July 11, 1918: Third rabbit died 8 days after feeding. Liver negative, lungs heavily infested with larvæ, 1 in trachea, 3 in esophagus, 1 in small intestine, 1 in stomach. Larvæ in lungs (13 specimens), 0.33 to 0.73 mm.; trachea, 0.75 mm.; stomach, 0.6 mm.; esophagus (3 specimens), 0.99 to 1.33 mm.

Experiment No. 16.

December 3, 1917: Rabbit fed eggs of *Ascaris suum.*

December 13, 1917: Rabbit died; lungs heavily infested. The lungs were cut into small pieces, placed in artificial gastric juice in the incubator and the larvæ digested out of the tissues.

December 14, 1917: Larvæ removed from the digestive fluid and placed in normal salt solution at room temperature.

December 17, 1917: Some larvæ still alive.

December 26, 1917: Some larvæ still alive.

January 4, 1918: Next examination, all dead.

Experiment No. 17.

Several years before the present series of experiments, the junior writer attempted to infest hogs by feeding one lot with the eggs of *Ascaris suum*, a second lot with eggs of *Ascaris lumbricoides*, and reserving a third lot as check animals. The different lots were kept in separate pens on ground where no pigs had ever been before. The feces of all the pigs were previously examined for *Ascaris* eggs and found free. At the end of about three months the pigs which had been given eggs of *Ascaris lumbricoides* were found positive, those given eggs of *A. suum* were still negative, while the check animals a few weeks later were found positive. No conclusions can therefore be drawn from the experiment.

Experiment No. 18.

The pigs used in this experiment were estimated to be between three and four months old when received, December 21, 1916, but it was nearly two months later before the first feeding with *Ascaris* eggs was given.

Precautions were taken to prevent outside infection after the experiment started and to insure that the animals were free from *Ascaris* before the experiment commenced. Of the 12 pigs used, 10 were found to be infested with *Ascaris* when purchased, and all 12 were given a dose of 2.5 mils of oil of chenopodium, with 1 ounce of castor oil. In our extensive experience with chenopodium we find that one dose is usually successful in removing all *Ascaris* present. In order to make doubly sure, however, three treatments with chenopodium were given, with intervals of five days to a week between doses, the last dose being given January 15, 1917. Four days later the feces of all the pigs were reexamined for *Ascaris* and all found negative. The animals were then taken from the pen, given a thorough scrubbing with soap and water, so as to reduce the chances of *Ascaris* eggs being carried over on the skin, and placed in clean pens with board floors, where no pigs had been before. Two of the animals died during the preliminary treatment; the remaining 10 were placed in three pens, as follows: Pen A, 2 check animals not given *Ascaris* eggs; pen B, 4 pigs given 1 feeding of *Ascaris* eggs; pen C, 4 pigs given repeated feedings of *Ascaris* eggs.

PEN B PIGS GIVEN ONE DOSE OF ASCARIS EGGS.

February 10, 1917: Pigs dosed with *Ascaris suum* eggs from cultures started December 14 and 29, 1916. Eggs from these cultures were also fed to mice, which subsequently developed verminous pneumonia.

March 4, 1917: Killed first pig 22 days after feeding *Ascaris* eggs. Five *Ascaris* in the small intestine, 4 of which measured 8.5 cm., 7 cm., 7 cm., and 6.5 cm. The fifth, apparently about the same size, was cut by the enterotome when the intestines were opened, and hence could not be measured.

March 7, 1917: Killed second pig 25 days after feeding *Ascaris* eggs. No *Ascaris* found.

March 21, 1917: Killed third pig 39 days after feeding *Ascaris* eggs. No *Ascaris* seen in small or large intestine or stomach. No larvæ found in spleen, lungs, or liver.

April 14, 1917: Killed fourth pig 63 days after feeding with *Ascaris* eggs. No *Ascaris* found.

PEN C PIGS GIVEN REPEATED DOSES OF ASCARIS EGGS.

February 24, 1917: Pigs given first dose of *Ascaris* eggs.

March 3, 1917: Second dose of *Ascaris* eggs.

March 20, 1917: Third dose of *Ascaris* eggs. Culture started February 27, 1917. This culture was subsequently fed to mice, and the resulting infestation proved the embryos were viable.

April 12, 1917: Fourth dose of *Ascaris* eggs.

April 27, 1917: Killed first pig 62 days after the first dose of *Ascaris* eggs, 15 days after the fourth dose. Two *Ascaris* in small intestine, 17 cm. and 19 cm., both the same age, to judge from their similarity in size. Liver, spleen, lungs, esophagus examined microscopically for larvæ; none found.

May 7, 1917: Fifth and last dose of *Ascaris* eggs given to the three remaining pigs.

June 4, 1917: Killed second pig 100 days since first feeding with *Ascaris* eggs, 28 days since the last feeding. No *Ascaris* found.

July 2, 1917: Killed third pig 128 days after first feeding with *Ascaris* eggs, and 56 days after the last feeding. Six female *Ascaris* were found, 23 cm., 24 cm., 25 cm., 26 cm., 26.5 cm., and 27 cm.; all in small intestine.

July 7, 1917: Killed fourth pig 133 days after the first feeding with *Ascaris* eggs, and 61 days after the last. Eleven female *Ascaris* were found, measuring 21 to 32 cm.

PEN A PIGS NOT FED ASCARIS EGGS.

July 7, 1917: Feces were again examined 167 days after the last fecal examination, when these pigs were first moved to their present quarters. The combined feces showed a few *Ascaris* eggs.

July 11, 1917: Feces of first pig examined; positive for *Ascaris*.

July 12, 1917: Feces of second pig examined; positive for *Ascaris*.

August 16, 1917: Reexamination of feces of first pig; *Ascaris* eggs present.

August 17, 1917: Reexamination of feces of second pig; *Ascaris* eggs present.

September 19, 1917: Feces of both pigs examined; *Ascaris* eggs present.

February 7, 1918: Feces of both pigs examined; both positive for *Ascaris*.

February 19, 1918: Second pig passed one large female *Ascaris* following dose of tartar emetic.

February 20, 1918: Both pigs killed. The first had 2 *Ascaris*, the second (which had passed 1 *Ascaris*) had 1 remaining.

Obviously the value of the conclusions to be derived from this experiment is weakened by the fact that the check animals were also infested, in spite of the precautions to guard against such a contingency. Considering the reliance which may be placed on a single dose of oil of chenopodium to rid hogs of *Ascaris* (as shown by Hall and Foster, 1918) and the fact that 3 such doses were given and the fecal examination following the last dose was negative, we have every reason to believe that the pigs were free from *Ascaris* when placed in the clean pen. Nevertheless, we can not be certain that the pigs were free from *Ascaris*, and they may have harbored young worms still in course of migration. There is also to be considered the possibility of the introduction of extraneous infection on the feet of the attendant or in the feed.

Considering first the experiment animals which were given but one feeding of *Ascaris* eggs, we find that only one of the four animals became infested in spite of the thousands of *Ascaris* eggs given to each pig, and this pig had but 5 worms—not a very convincing proof of the direct life cycle of the pig *Ascaris*. Furthermore, although the worms found were all about the same length, indicating that they came from the same infection, they had reached a rather large size, too large apparently for infection to have occurred only 22 days before.

Among the pigs which had received repeated doses of *Ascaris* eggs, 3 out of 4 were infested, the heaviest infestation being 11 *Ascaris*, the lightest 2 *Ascaris*. It is impossible to decide whether or not the worms found in these animals came from the eggs fed to them. Naturally, in view of the large number of eggs fed, massive infestations would have been expected. This, however, was not the case. A possible indication that the worms found actually came from the eggs fed to the pigs in pen C is that the average size of the worms from the pig killed 133 days after the first feeding and 61 days after the last is greater than that of the worms from the pig killed 62 days after the first feeding and 15 days after the last.

Experiment No. 19.

Our failure in Experiment No. 18 to infect all the animals that were fed eggs, and to get massive infestations, together with the fact that our check animals became infested, led us to repeat the experiment. About this time the finding of ascarids in the lung of a young pig, as already recorded (Ransom and Foster, 1917), and the fact that young animals have long been known to be particularly susceptible to parasitic infestation, suggested that more successful results from infection experiments might be obtained if very young pigs were used as subjects.

With the idea of obtaining animals as young as possible and to reduce the chances of prior infection it was decided to take a pregnant sow, eliminate all ascarids by treatment, place the sow in a clean pen for farrowing, and feed the little pigs with *Ascaris* eggs as soon as they could be handled. After numerous disappointments, a pregnant sow was procured, which, however, gave birth to 5 pigs before it could be examined and treated for *Ascaris*. Two weeks after the birth of the pigs (of which 2 only remained alive), the feces of the sow were examined. One *Ascaris* egg was seen in the first examination and others in a subsequent examination. There was considerable doubt after the first examination whether the single egg seen came from a contamination of the fecal sample or indicated a slight infestation. At any rate it was evident that if the sow was infested the little pigs had already had an opportunity to pick up eggs from the sow's feces, and it was therefore decided not to disturb the sow by anthelmintic treatment, but to proceed directly with the experiment on the pigs.

September 22, 1917: Dosed one of the little pigs with culture of eggs of *Ascaris suum*. Pig 15 days old when treated.

September 29, 1917: Pig died 7 days after dosing with *Ascaris* eggs.

October 1, 1917: Post-mortem of pig. *Ascaris* larvæ numerous in lungs, trachea, and pharynx. None found in liver, spleen, esophagus, small or large intestine. Larvæ from the trachea varied from 0.67 to 1.33 mm. in length, 0.03 to 0.06 mm. in width, with esophagus 0.12 to 0.21 mm. in length.

October 4, 1917: Fed second pig with 5 c. c. of a culture of eggs of *Ascaris suum*. Pig now 27 days old.

October 16, 1917: No signs of pneumonia.

November 10, 1917: Second feeding of *Ascaris* eggs.

November 17, 1917: Killed pig 44 days after the first feeding, 7 days after the second. Liver and lungs both show numerous petechiæ similar to those found in other experiment animals and associated with the invasion of these organs by *Ascaris* larvæ. However, no larvæ were seen in the preparations examined. The small intestine contained 8 immature *Ascaris*, 3 of which were accidentally cut by the enterotome. The remaining 5 measured as follows: Length, 88 mm., 78 mm., 70 mm., 65 mm., and 60 mm.; width, 1.5 mm., 1.3 mm., 1.2 mm., 1 mm., and 1 mm.

November 28, 1917: Feces of sow examined; several *Ascaris* eggs seen.

November 30, 1917: Sow killed; 7 *Ascaris* in small intestine, measuring 16 to 21 cm. long.

This experiment, like the preceding, is open to the criticism that outside sources of infection were not excluded, since the pigs for the first month of life were in intimate association with the mother which at the post-mortem was proved to have been infested. This, however, has no bearing on the findings in regard to the first pig which died of verminous pneumonia. The heavy infestation in this case could not conceivably have resulted in any other way than from the massive dose of eggs given 7 days before. In regard to the second pig which was found infested with intestinal ascarids 44 days after the initial feeding of eggs, it is less certain that the worms came from the eggs that were fed. Yet the fact that all the worms found were of nearly the same size and, assuming that it takes about 2½ months for adults to develop in the pig, as it has been shown is necessary in the case of the human *Ascaris*, the facts that the worms were immature and of a size that might reasonably be expected after 44 days of growth, are not inconsistent with the presumption that the worms found came from the eggs that were fed to the animal.

Experiment No. 20.

Two young suckling pigs were used, one fed with eggs of *Ascaris lumbricoides* containing vermiform embryos, the other reserved as a check animal. Both pigs and the sow were transferred to a clean board pen soon after the pigs were born and the feces of the sow were frequently examined for evidences of *Ascaris* infestation. Throughout the experiment the feces were negative. Eighty-one days after the feeding with *Ascaris* eggs the pig was slaughtered but no *Ascaris* was found in the small intestine nor in any of the organs usually invaded by the larvæ. Seventeen days later the check animal was slaughtered and was also found free from *Ascaris* infestation. Some of the same culture of eggs used in this experiment was fed to guinea pigs, whose lungs became heavily infested with larvæ, so there is no question as to the viability of the eggs.

Experiment No. 21.

In this experiment 5 newborn pigs were used, date of birth, March 22, 1917. Three pigs were fed with the same culture of eggs used in Experiment No. 20, and 2 pigs were kept as checks. All 5 were kept with the sow in a recently built clean pen.

March 30, 1917: First pig received about 5 c. c. of a culture of eggs of *Ascaris lumbricoides*. Second pig received about 6 c. c. Third pig received about 4 c. c.

April 8, 1917: Pig No. 2 died 9 days after feeding. The lungs were spotted with numerous ecchymoses but not intensely hemorrhagic as in laboratory animals dying of verminous pneumonia. The spleen and thyroid were negative. One larva was found in the liver, the lungs were heavily infested, larvæ were numerous in the trachea, while one larva was found in the pharynx and one in the esophagus. Larvæ in the trachea varied from 0.85 to 1.04 mm. in length, with esophagus from 0.09 to 0.13 mm. long.

May 6, 1917: Sow removed from the pen. While with the pigs four fecal examinations were made at intervals, all of which proved negative.

June 3, 1917: First pig slaughtered and examined 65 days after feeding. Lungs showed lesions of broncho-pneumonia. There were 2 large hemorrhagic areas in which 2 degenerated *Ascaris* larvæ were seen. Trachea, esophagus, stomach, intestines, spleen, and liver were negative for *Ascaris*.

July 5, 1917: The third pig was slaughtered 97 days after feeding. Lungs, bronchi, trachea, esophagus, small and large intestines were all examined, but no *Ascaris* found.

July 17, 1917: Fourth pig (check animal) slaughtered and examined 109 days after feeding pigs 1, 2, and 3. Negative for *Ascaris*.

July 26, 1917: Fifth pig (second check animal) slaughtered and examined 118 days after feeding pigs 1, 2, and 3. Negative for *Ascaris*.

It might appear from these experiments that *Ascaris lumbricoides* can not develop beyond the lung stage in pigs, and that therefore there is a biological if not a morphological difference between the *Ascaris* of man and that of pigs, the *Ascaris* of man not being able to develop in the pig. Of 4 pigs fed very large doses of eggs only 2 showed any infestation, and in neither of these did the worms develop beyond the lung stage. It is true that 1 of the 4 pigs died when the parasites were actively migrating out of the lungs, and in this case the death of the host certainly interfered with further development of the larvæ, but of the 3 remaining pigs, all of which received large numbers of eggs, only one showed any infestation, and apparently in this case the larvæ that succeeded in reaching the lungs never developed further.

It is, however, hard to believe that the digestive apparatus of the pig is so different from that of man that an *Ascaris* morphologically indistinguishable from the form found in man would be unable to develop at least to an immature stage in the intestine of swine. As shown in another experiment *Ascaris suum* may develop in lambs to immature worms of considerable size, and it may also be noted that Jammes and Martin (1906) succeeded in rearing *Ascaris vitulorum* to a considerable size in a man to whom the eggs of the parasite had been administered. Yet the difference between the digestive apparatus of sheep and swine is certainly greater than that between swine and man, and undoubtedly the *Ascaris vitulorum* of calves is a distinct species from *Ascaris lumbricoides* of man. The failure to obtain at least immature worms if not mature worms in the intestines of pigs following the feeding of eggs of *A. lumbricoides* can therefore scarcely be explained upon the basis of a biological difference between the *Ascaris* of man and that of the pig.

Experiment No. 22.

March 2, 1918: Fed a 2-day-old lamb with about 3 cubic centimeters of a culture of *Ascaris suum* eggs which had been prepared January 9.

June 13, 1918: Lamb killed 103 days after feeding. Apices of lungs consolidated. No *Ascaris* larvæ found in the lungs. Duodenum showed numerous ecchymotic spots and 50 half-grown *Ascaris*, 12 males, 38 females. Males were 60–110 mm. long, average 88 mm.; females 60–132 mm. long, average 91 mm. Three worms were over 130 mm. long. Most of the specimens were between 75 and 110 mm.

Experiment No. 23.

July 3, 1918: Fed a 4-day-old kid with a large dose of eggs of *Ascaris suum* incubated since April 4, 1918. The kid showed no ill effects from this dose.

July 20, 1918: Second feeding with *Ascaris suum* eggs, one-half ounce of the culture being given in milk.

July 27, 1918: The kid shows symptoms of pneumonia 24 days after the first feeding, 7 days after the second feeding. High temperature, abdominal breathing, occasional hard, dry cough; animal appears listless, but appetite is still good. Eyes are somewhat inflamed, coat staring, animal lies down most of the time.

July 28, 1918: Same symptoms as before. Gave three 1/50-grain strychnin tablets as a heart stimulant.

July 30, 1918: Kid refuses all food, grows rapidly worse, and dies at 4.30 p. m., 27 days after the first feeding, 10 days after the second.

July 31, 1918: Post-mortem. Liver shows extensive cirrhosis, but no larvæ are seen. Lungs intensely hemorrhagic and edematous; loaded with larvæ ranging from 0.95 to 1.85 mm. in length, most of the forms measured being well over 1 mm. Thymus, spleen, and thyroid negative. Larvæ in trachea, pharynx, and esophagus very abundant. Trachea, pharynx, and esophagus show diffuse inflammation of the mucous surfaces. Larvæ numerous in first stomach and in fourth stomach, the latter showing diffuse inflammation. The small intestine contained thousands of young ascarids varying in length from 4.3 to 11.4 mm., averaging 7.9 mm. (29 specimens measured). Presumably these latter were derived from the first feeding and are therefore 27 days old, while the smaller forms in the lungs, trachea, esophagus, and stomach are the result of the second feeding and are therefore 10 days old.

GENERAL SUMMARY.

The embryos in the eggs of *Ascaris suum* or *A. lumbricoides* in the presence of oxygen and moisture may reach full development in 10 days if incubated at a temperature of about 33° C., development proceeding more slowly at lower temperatures and being inhibited by the lack of oxygen or moisture.

The shell of the egg is insoluble in many chemical reagents. Within the shell there is a thin membrane which is highly impermeable and even more resistant to solution than the shell itself. The shell may be dissolved with antiformin, leaving the embryo inclosed in the membrane, in which condition the embryo may continue active for several days.

Hatching of the embryo may occur accidentally outside the body of a host, but occurs normally only in the small intestine. Hatching also occurs if the egg is introduced beneath the skin. The factors that govern the hatching of *Ascaris* eggs are yet to be determined. Martin's conclusions that hatching is caused by alkaline or even neutral solutions acting at body temperature have not been confirmed.

Ascaris eggs in large numbers may be conveniently obtained and developed to the infectious stage for experimental use by removing the eggs from the uteri of female worms and incubating them in a solution of formalin placed in shallow dishes and stirred every few days to insure sufficient aeration.

If *Ascaris* eggs containing fully developed embryos are swallowed by rats, mice, guinea pigs, or rabbits they hatch in the small intestine. Some of the newly hatched larvæ may be eliminated in the feces, but others penetrate the wall of the alimentary tract and apparently aided by the circulation migrate to the liver and lungs; they may also migrate to the spleen and thyroid and under the peritoneum of the abdominal cavity. Most of those entering the liver later migrate to the lungs. In the course of their migrations the larvæ undergo growth and development, reaching five to ten times their original length before leaving the lungs, after which no material change occurs in size or structure. Larvæ that do not reach the lungs ultimately die and become encysted or absorbed by the surrounding tissues. From the lungs the larvæ crawl up the trachea, then down the esophagus through the stomach into the intestine, and finally pass out of the body in the feces. They may be found in the liver as early as 2 days after infection, in the lungs and trachea as early as 3 days after infection, and in the alimentary tract after their passage through the lungs as early as 6 days after infection. They are common in the lungs a week to 10 days after infection, becoming scarce in the liver as they become numerous in the lungs. Within a little over two weeks after infection all or practically all the larvæ are usually eliminated, but have been found still present and active in the liver, lungs, and alimentary tract as late as 23 days after infection.

In young goats and lambs the larvæ of *Ascaris suum* after migrating through the lungs settle down in the small intestine and undergo development approaching maturity, these animals thus being better adapted as hosts than rats, mice, guinea pigs, and rabbits.

In pigs *Ascaris* larvæ after migrating through the lungs settle down in the small intestines and develop to maturity, and presumably the same cycle occurs in human beings.

Rats and mice play no part in the normal life history of *Ascaris*. The behavior of the larvæ in these animals and in guinea pigs and rabbits may be considered simply an expression of imperfect adaptation of the parasites to existence in these hosts.

In pigs and human beings *Ascaris* may develop to maturity within two and one-half months after infection.

In guinea pigs the larvæ apparently reach a larger average size than in mice in the same length of time, and still larger in rabbits.

Migrating *Ascaris* larvæ produce destructive lesions in the liver and lungs, especially in the latter.

Some larvæ die during their migrations. Dead and degenerated larvæ have been found in the lungs as late as 86 days after infection, and in the liver 296 days after infection.

The invasion of the lungs by *Ascaris* larvæ may result in a serious and sometimes fatal pneumonia, which appears in a week to 10 days after ingestion of the eggs.

Young pigs are more susceptible to *Ascaris* infection than older animals, but may not entirely lose their susceptibility with advancing age.

No evidence has been obtained that one infection with *Ascaris* renders animals less susceptible to later infections.

If properly incubated *Ascaris* eggs are injected beneath the skin they will hatch, and the larvæ will migrate to the lungs, where they may be found a few days after injection of the eggs to have reached the same stage of development as they would if infection had occurred from swallowing the eggs.

The larvæ of *Belascaris marginata* undergo migrations in rats similar to those of *Ascaris suum* and *A. lumbricoides*.

Immature stages of a nematode resembling and probably identical with *Ascaris anoura* have been found in the lungs of a python, indicating that this species, like *Ascaris lumbricoides* and *Belascaris marginata*, migrates through the lungs, reaching, however, a more advanced development before moving into the alimentary tract.

The larvæ of *Hæmonchus contortus* ingested by guinea pigs can be found in the lungs 2 days later, indicating the possibility that this species migrates through the lungs before finally establishing itself in the alimentary tract.

Migration of the larvæ through the lungs is probably a common occurrence in the life cycle of nematodes whose adult stage occurs in the alimentary tract.

Stewart's observations as to the migration of *Ascaris* larvæ through the lungs have been confirmed, but his suggestion that rats and mice act as intermediate hosts is not tenable. No intermediate host is necessary, and human beings and pigs become infected with *Ascaris* as a result of swallowing the eggs of the parasite, and not as a result of swallowing food, water, or other substances that have been contaminated by the feces of rats or mice.

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WM. A. TAYLOR, Chief

Washington, D. C. **PROFESSIONAL PAPER** **January 5, 1920**

SOIL DISINFECTION WITH HOT WATER TO CONTROL THE ROOT-KNOT NEMATODE AND PARASITIC SOIL FUNGI.

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OBJECTS OF THE INVESTIGATIONS.

The experiments described in the following pages were undertaken to obtain more accurate data on the effectiveness of hot water as a means of ridding soil of the root-knot nematode (*Heterodera radicicola*) (Greef.) Müller) and parasitic fungi usually associated with damping-off and other root troubles.

The great need of a simple, practical method for disinfecting small quantities of soil in which to grow healthy seedlings for home-garden planting has always existed, but because of the great extension of tomato and other club work in recent years, the need has become more pronounced and more apparent. Such a method would also be especially adapted for disinfecting soil in pots and shallow greenhouse benches. Very successful results have been obtained by one of the writers in killing the root-knot nematode in infested dasheen tubers, to be used for planting purposes, by soaking them in hot water, without appreciably impairing their viability. Furthermore, a method of soil disinfection by hot water has been used with some success in vegetable greenhouses in the Boston district, but no careful experiments have been carried out to determine the temperatures required or the quantity of water necessary to control the soil troubles successfully. It is not thought that the hot-water method will take the place of steam for soil-disinfecting purposes where steam can be advantageously used. On the other hand, it is intended for use where steam is not available or where its use is for any reason impracticable. Many greenhouses are so constructed that the use of inverted pans for steaming the soil is not feasible. In some greenhouses the capacity of the boilers is not sufficient to furnish the high pressure steam required for disinfecting purposes. For disinfecting small quantities of soil in pots or flats, to be used in growing seedling plants for home gardens or in greenhouses, steam is rarely available, and its use is often impracticable.

So far as the writers have been able to ascertain, the only investigations that have been carried out with hot water for soil disinfection are those of Stone and Smith in "The Rotting of Greenhouse Lettuce," Bulletin 69 of the Massachusetts (Hatch) Agricultural Experiment Station, published in 1900. Working with deep ground beds of greenhouse soil, they found that by the liberal application of water at 210° F. as it came from the hose the temperature of the upper 4 inches of soil was raised to 176° to 186° F. The treatment completely killed the Rhizoctonia and reduced the amount of lettuce drop caused by *Sclerotinia libertiana* 76 per cent.

In carrying out the investigations here reported, two series of experiments were performed, the second being in a large measure a repetition of the first, but with certain changes and additions suggested as a result of the first tests.

EXPERIMENT SERIES I.

METHOD OF PROCEDURE.

SOIL.

The soil used in the experiments was a light, loose, sandy mixture made of about one-third standard greenhouse soil and two-thirds sand. Such a mixture is very favorable for the growth of nematodes. For some time previous to the initiation of the experiments, the soil had been in a bench section in the greenhouse which had been used for growing tomatoes for maintaining a large stock culture of nematodes. It was, therefore, well infested with the root-knot nematode and with damping-off fungi, as was shown by previous results on tomatoes grown therein as well by the subsequent observations with untreated checks. To insure uniform physical condition and uniform distribution of the pathogenes throughout the entire mass of soil, it was thoroughly mixed by shoveling over several times, and was then sifted through a coarse screen. To obtain more abundant infection, in in some cases, as noted in detail below, tomato roots severely diseased with root-knot were cut up into small pieces and mixed with the soil.

TREATMENT OF THE SOIL.

The soil was then placed in standard 4 and 8 inch unglazed earthen pots and in a section of a raised greenhouse bench. Inasmuch as the soil in different containers received different treatments, each series of experiments is here considered separately.

Four-inch pots.—The 4-inch pots were treated by immersing them for 2½, 5, and 10 minutes, respectively, in boiling water at 98° C. (208° F.). Three pots were included in each treatment, and one was left untreated as a check. The soil used was taken from the greenhouse bench described, but was not further infected by the addition of nematode-infested roots. During the immersion of the pots the water was kept boiling by means of two large Bunsen burners. The check pot was immersed for a short time in cold water. Following the immersion, the pots were removed and the surplus water allowed to drain off. They were then placed on the greenhouse bench, which was covered with a layer of fresh cinders, to reduce the possibility of reinfestation with nematodes, and allowed to dry for five days before planting.

This experiment was duplicated, using the same sifted soil plus nematode galls of tomato roots. These galls were cut up into small pieces, about one-third inch long, and mixed with the soil in the top half of the pots.

Eight-inch pots.—The 8-inch pots were filled with the infested soil to within 1 to 1½ inches of the top when well shaken down. Three pots each were then treated by applying 1,000, 2,000, and 3,000 c. c., respectively, of boiling water at 98° C. (208° F.). An additional pot was thoroughly wet down with cold water and left as a check. In the case of the 1,000 c. c. treatment, the boiling water was all applied at one time, but with the larger treatments it was added as rapidly as it penetrated the soil.

As soon as the respective quantities of water were added, the pots were covered with newspapers to hold in the heat, and the surplus water was allowed to drain off. The pots were then left on the greenhouse bench to dry for five days previous to planting.

This experiment was also duplicated, using sifted infested soil plus nematode-infested tomato roots cut up and thoroughly mixed with the topsoil in the pots.

Greenhouse bench.—A portion of a greenhouse bench about 3 by 4 feet was divided into four sections approximately 18 by 26 inches by means of 1-inch boards which extended to the bottom of the bench and about 2 inches above the surface of the soil, which was about 5 inches deep. The soil was the same as that used for the pot experiments described above, except that it was not sifted and did not receive additional nematode-infested tomato roots.

Section 4 received an application of approximately 17,000 c. c. (17 liters) of cold water and acted as a check. To sections 1, 2, and 3 were applied, respectively, 8,500, 13,500, and 17,000 c. c. of boiling water, which is approximately equivalent to an application of 750, 1,000, and 1,500 c. c. per 8-inch pot of soil. In the case of section 1 the whole quantity was applied at one time; on sections 2 and 3 the hot water was applied in two doses put on a few minutes apart, for the reasons that the soil would not take up the entire volume of water at one time, and, furthermore, the means for heating this quantity at once were not at hand. In the case of section 1 the water applied was sufficient to wet thoroughly all the soil, and a small proportion ran through. In sections 2 and 3 a considerable proportion of water ran through, but it was noted that the first dose compacted the soil to a certain extent, so that the second dose ran through but slowly. To further assist in holding the heat in the soil, the sections were covered with newspapers immediately following the treatment. The bench sections were left for seven days, to allow the soil to dry out sufficiently for planting.

PLANTING OF SEED.

In the 4 and 8 inch pot experiments, Stone tomato seeds were sown five days after the treatment, fairly thick, but as uniformly as possible. In the bench sections two rows each of Stone tomatoes and Big Boston lettuce were sown in a similar manner, especial care being taken to make the sowings as uniform as possible in the different sections.

RESULTS.

The results from these experiments were recorded in the form of comparative germination counts taken two weeks after planting, and notes made at intervals on the damping-off and nematode infection and on the size and vigor of the plants. All the plants were allowed to grow for about seven weeks, and the experiment was then terminated. All the plants were removed from the pots and benches, and the soil was washed carefully from the roots, especial care being taken to preserve the entire root systems intact. The plants were then examined for nematode galls or injuries due to the attacks of soil fungi, records being made of the number and severity of each. Isolations were made to determine the organism responsible for the damping-off and root discolorations found. *Pythium debaryanum* was found to be the cause of damping-off, while Rhizoctonia species caused stem lesions and root discolorations. All data obtained were supported by photographs taken at various stages during the progress of the experiment to illustrate the important results noted. The details of the results are given in Tables I and II.

Table I.—*Soil-disinfection tests with tomato plants grown in 4-inch and 8-inch pots, with hot-water treatment, in February and March, 1918.*

[All the pots were filled with nematode-infested soil thoroughly mixed by sifting, soil *A* being without the addition of diseased tomato roots and soil *B* having such addition.]

Size of pots, kind of soil used, and treatment of soil-filled pots.	Pot No.	Number of living plants.		Results observed on Mar. 7 (end of experiment).[1]								
		On Feb. 5.[2]	On Mar. 7.	Nematode infestation of roots.						Pythium and Rhizoctonia infection of roots.	Plant notes.	
				Severe.	Medium.	Mild.	Total.	Percentage.			Height (inches).	Color.
								By pot.	By treatment.			
Four-inch pots, soil *A*: Immersed in boiling water—												
2½ minutes	1	32	31	0	0	0	0	0	0	Wh	5 to 6.	Hg.
	2	40	43	0	0	0	0	0				
	3	37	39	0	0	0	0	0				
5 minutes	1	43	44	0	0	0	0	0	0	Wh	5 to 7.	Hg.
	2	37	37	0	0	0	0	0				
	3	36	36	0	0	0	0	0				
10 minutes	1	78	75	0	0	0	0	0	0	Wh	..do..	Hg.
	2	30	29	0	0	0	0	0				
	3	37	39	0	0	0	0	0				
Check (immersed in cold water)	1	7	6	0	2	2	4	66	83	Db	3.....	Sg.
	2	17	6	3	3	0	6	100				
Four-inch pots, soil *B*: Immersed in boiling water—												
2½ minutes	1	88	58	0	0	0	0	0	0	Md.	5 to 6.	Hg.
	2	25	26	0	0	0	0	0		Wh		
	3	33	34	0	0	0	0	0		Wh		
5 minutes	1	64	65	0	0	0	0	0	0	Wh	5 to 7.	Hg.
	2	40	45	0	0	0	0	0				
	3	45	52	0	0	0	0	0				
10 minutes	1	33	47	0	0	0	0	0	0	Wh	..do...	Hg.
	2	22	20	0	0	0	0	0				
	3	42	42	0	0	0	0	0				
Eight-inch pots, soil *A*: Boiling water poured into pots—												
1,000 c. c.	1	52	31	0	0	14	14	45	20.5	Nad	3 to 4.	Yg.
	2	82	83	0	0	21	21	25				
	3	69	66	0	0	2	2	3				
2,000 c. c.	1	70	73	0	0	6	6	8	8.8	Nd	4 to 5.	Dhg.
	2	104	101	0	2	11	13	13		Sd.		
	3	76	75	0	0	3	3	4		Wh		
3,000 c. c.	1	121	126	0	0	0	0	0	0	Wh	..do..	Dhg.
	2	86	88	0	0	0	0	0				
	3	87	86	0	0	0	0	0				
Check (drenched with cold water)	1	34	13	15	2	3	10	77	83	Db	2.....	Sg.
	2	11	5	13	1	1	5	100				
Eight-inch pots, soil *B*: Boiling water poured into pots—												
1,000 c. c.	1	66	65	0	0	16	16	24	19.6	Nad	3 to 4.	Yg.
	2	76	71	0	0	13	13	18				
	3	84	76	0	4	8	12	16				
2,000 c. c.	1	85	76	0	0	17	17	22	16.7	Sd.	4 to 5.	Dhg.
	2	52	52	0	0	4	4	8				
	3	81	80	0	0	14	14	17				
3,000 c. c.	1	55	56	0	0	0	0	0	0	Wh	..do..	Dhg.
	2	66	96	0	0	0	0	0				
	3	52	46	0	0	0	0	0				

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[1] Abbreviations used: Db=Discolored, badly diseased; Dhg=Dark, healthy green; Hg=Healthy green; Md=Many discolored; Nad=Nearly all discolored; Sd=Slight discoloration; Sg=Sickly green; Wh=White, healthy; Yg=Yellow green.

[2] Two weeks after planting.

DISCUSSION OF RESULTS.

From a study of the data presented in Table I, relative to the two sets of 4-inch pot treatments, the results are here summarized.

1. As a result of submersion of the soil in boiling water for 2½, 5, and 10 minutes, no infection by root-knot nematodes, Pythium, or Rhizoctonia occurred in either set of pots except in one pot which showed a small amount of Rhizoctonia root discoloration. As this minor infection occurred in one of the pots to which diseased roots were added and which received the 2½-minute submersion, it is quite probable this was due to insufficient treatment. The plants in the check pots showed 83 per cent affected by nematodes and 100 per cent severely diseased by the fungous parasites. A comparison of the typical appearance of roots from treated pots and those from untreated check pots is shown in Plate I, figure 1.

2. Normal germination occurred in all treated pots, an average of 42 plants per pot, while in the untreated pots the stand was reduced by the soil organisms to an average of 12 plants per pot.

3. All treatments prevented damping-off in both sets of pots, as was shown by the final examination, while in the untreated check pots half of the seedlings died after the first germination count made two weeks subsequent to planting. (Pl. I, fig. 2.)

4. Throughout the experiment the plants in the check pots showed pronounced yellowing and stunting, reaching an average height of only 3 inches at the time of the final examination, as compared to an average height of 5 to 7 inches for the plants in treated soil, all of which were vigorous and of a healthy green color.

Certain facts evident from a study of that part of the data in Table I pertaining to the two sets of 8-inch pot experiments are here presented.

1. The 18 treated pots showed an average of 74 seedlings per pot two weeks after planting, as compared with an average of 22 for the two check pots, a reduction of 70 per cent in the stand. The typical appearance of treated and untreated pots at this time is shown in Plate II, figure 1.

2. A slight amount of damping-off occurred in two of the six pots receiving the 1,000 c. c. treatment, while none was noted in the 12 pots which received the larger amounts of boiling water. In the check pots, however, almost 60 per cent of the seedlings damped-off between the first germination count and the final notes.

3. The plants in the check pots remained markedly stunted throughout the experiment, attaining a final average height of only 2 inches, and were considerably yellowed and unhealthy in appearance. The plants grown in pots receiving 1,000 c. c. of boiling water reached a final height of 3 to 4 inches and were slightly yellow in color. The plants in all pots receiving the larger treatments grew

to 4 to 5 inches in height, and all were vigorous and healthy in appearance. Differences existing at the end of the experiment in number, size, and general appearance of the plants in pots receiving the different treatments are shown in Plate II, figure 2. Compare with Plate II, figure 1, which shows some of the same pots at a very early stage in the experiment.

4. The application of 3,000 c. c. of boiling water per 8-inch pot (180 cubic inches of soil) gave complete control of both nematodes and soil fungi in both sets of pots. Applications of 1,000 c. c. and 2,000 c. c. gave partial control of the pathogenes. An average of 20 and 13 per cent, respectively, of the plants in these pots showed mild nematode infection, as compared with 83 per cent of nematode infection in the check pots, most of which was severe. In two of the six pots receiving the 2,000 c. c. treatment no Rhizoctonia infection occurred, while plants in the remaining pots showed slight root discolorations. Nearly all plants, however, which received the 1,000 c. c. treatment showed root discolorations. The roots of the plants in the untreated check pots were badly discolored, many being entirely destroyed by the fungous parasites. A comparison of the appearance of the roots from plants grown in treated and untreated soil is shown in Plate III.

TABLE II.—*Soil-disinfection tests with tomato and lettuce plants grown in shallow bench sections, with hot-water treatment, in February and March, 1918.*

[The bench sections were 5 to 6 inches deep and filled with nematode and fungus-infested soil thoroughly mixed by sifting.]

Kind of plants and bench section No.	Size of bench sections.	Application of boiling water (at 98° C.).			Damping-off on Feb. 5.	Results observed on Mar. 8, 1918 (end of experiment).									
							Nematode infestation of roots.					Pythium and Rhizoctonia infection of roots.		Plant notes.	
		Total quantity.	Number of doses.	At rate per 8-inch pot.		Total plants.	Severe.	Medium.	Mild.	Total.	Percentage.	Number of plants.	Percentage.	Height.	Color.[1]
Tomato:	*Inches.*	*C.c.*		*C.c.*	*No.*									*In.*	
1	26 by 18	8,500	1	750	3	108	0	0	43	43	40	66	61	6	Hg.
2	26 by 16	13,500	2	1,000	0	94	0	0	28	28	30	0	0	6	Hg.
3	24 by 18	17,000	2	1,500	0	204	0	4	10	14	7	3	14	7	Hg.
4 check[2]	24 by 16				15	75	15	21	18	54	72	75	100	4	Sy.[3]
Lettuce:															
1	26 by 18	8,500	1	750	65	178	0	28	43	71	40	178	100	2½	Y.
2	26 by 16	13,500	2	1,000	5	197	0	0	21	21	11	32	16	3	Hg.
3	24 by 18	17,000	2	1,500	0	210	0	0	2	2	1	0	0	5	Hg.
4 check[2]	24 by 16				25	32	6	12	2	20	64	32	100	2	Sg.[4]

[1] Abbreviations used: Hg=Healthy green, Sg=Sickly green, Sy=Stunted yellow.
[2] Saturated with cold water. [3] Poor stand. [4] Stand 25 per cent.

From the details of the bench experiments, which are given in Table II, the results are here briefly stated.

1. Damping-off of both lettuce and tomato seedlings on February 5 was quite prevalent in the check and in the section receiving 8,500 c. c. of boiling water, while it was found only to a slight extent in the 13,500 c. c. treated section and not at all in the 17,000 c. c. treatment.

2. The average percentages of netamode infection occurring on lettuce and tomato plants grown in treated sections Nos. 1 to 3 and check section No. 4 were as follows: 40, 20, 4, and 68. For Rhizoctonia they were 80, 8, 7, and 100. These figures indicate control of the pathogenes in proportion to the amount of the hot-water applications. A comparison of healthy plants from the 17,000 c. c. section with typical nematode and Rhizoctonia diseased plants, from the check section is shown in Plate IV, figure 1.

3. In the case of both test crops, while the plants in the untreated section, No. 4, were dwarfed and yellowed, in the treated sections they were of larger size and greater vigor the larger the amount of hot water applied. The stand in the check sections was greatly reduced. These points are clearly brought out in Plate III, figure 2.

EXPERIMENT SERIES II.

In studying the results secured from the preliminary experiments already presented, additional data were desired to answer certain questions which arose, viz: How much of the vigor and increased growth of the plants in treated soil was due to the physical and chemical effects of the heating on the soil, and how much to the absence of plant pathogenes? What temperatures were secured in the soil by the various treatments given and for what lengths of time were they maintained?

To answer these questions and also to make our results the more conclusive, on May 3 the entire series of experiments was repeated with more checks and with such changes and additions as would give the desired information.

METHOD OF PROCEDURE.

SOIL.

Two lots of soil were used in the 4 and 8 inch pot experiments, viz, infested soil and presumably uninfested greenhouse soil. The infested soil used was the nematode and fungus infested soil from the previous bench experiment with the addition of infested soil from the tomato bed used as a stock culture for nematodes. This was thoroughly mixed and sifted and was further infected with nematodes by mixing with the soil in the pots badly nematode-diseased tomato roots cut into small pieces. The greenhouse soil was from a fresh mixture not yet used in greenhouse work and presumably free from the parasites under consideration.

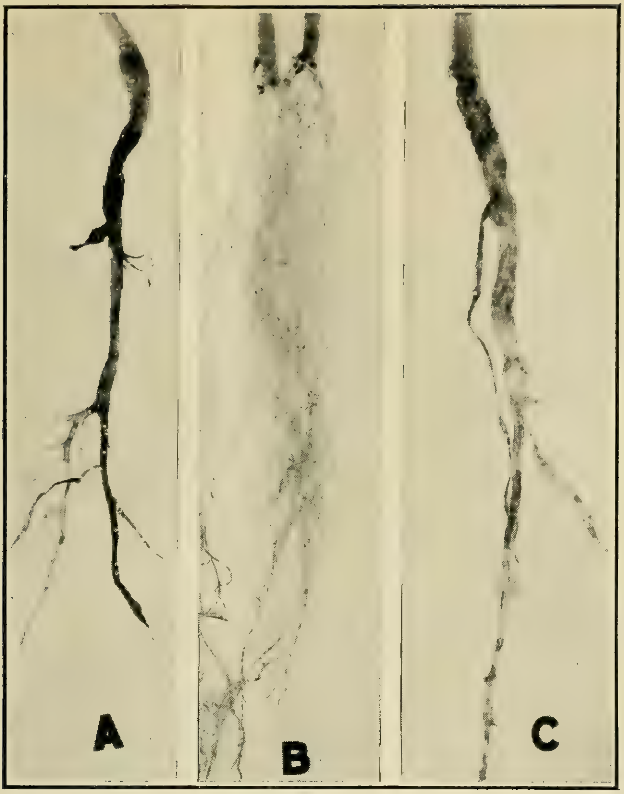

FIG. 1.—TOMATO PLANTS FROM TREATED AND UNTREATED 4-INCH POTS OF EXPERIMENT SERIES I.

B, Uninfected healthy roots grown in nematode and fungous infested soil submerged for 2½ minutes in boiling water (98° C.) (natural size); *A* and *C*, plants with nematode root and stem galls and Rhizoctonia root discolorations grown in untreated infested soil in check pots. (Enlarged three times.)

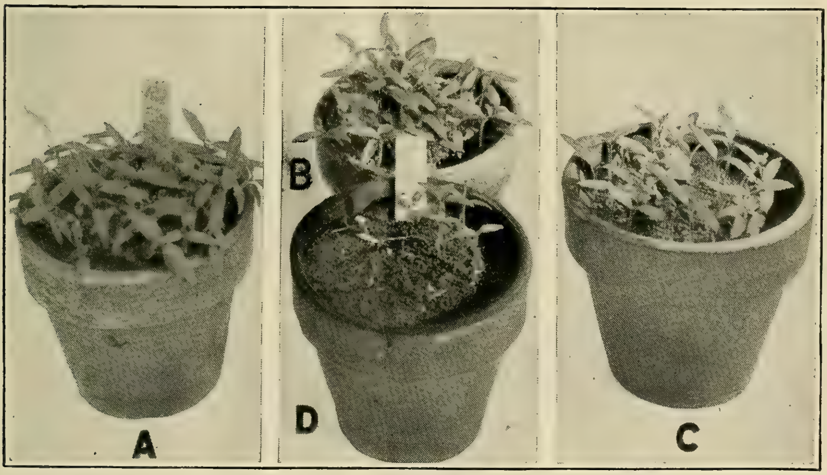

FIG. 2.—FOUR-INCH POTS OF EXPERIMENT SERIES I TWO WEEKS AFTER PLANTING.

Note the full stand and vigorous appearance of the tomato seedlings in pots *A*, *B*, and *C* submerged for 2½, 5, and 10 minutes, respectively, in boiling water, compared with the very poor stand, smaller size, and damping-off of plants in the untreated check pot *D*.

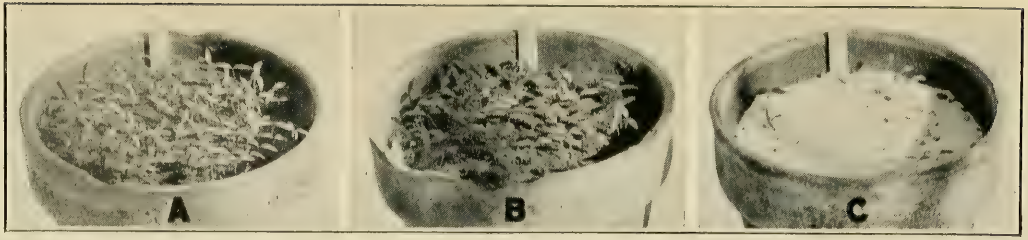

FIG. 1.—Note the full stand and vigorous appearance of the seedlings in pots *A* and *B*, which received the 3,000 and 1,000 c. c. treatments, respectively, as compared with the very poor stand and small size of seedlings in the check pot, *C*.

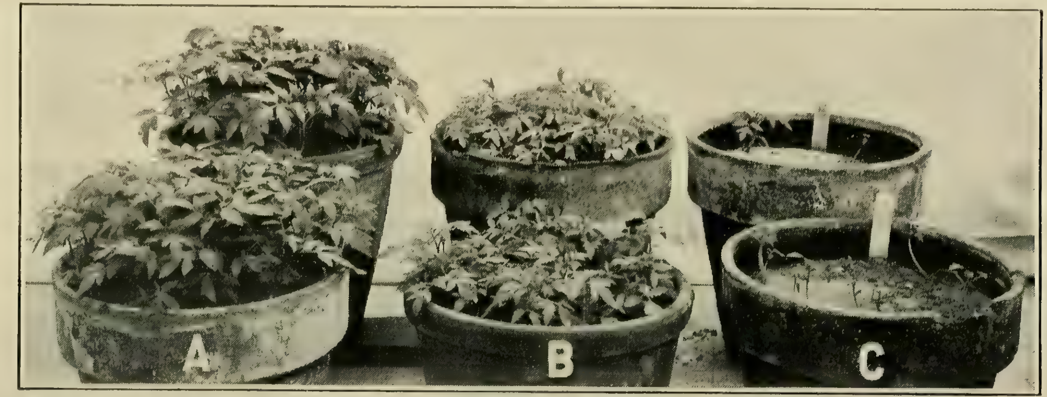

FIG. 2.—*A*, A full stand of large, vigorous plants, subsequently found free from root-knot and other diseases (see Pl. III, fig. 1–*A*), grown in soil receiving 3,000 c. c. of boiling water. *B*, A fair stand of slightly yellowed plants, smaller than those in *A*, later found slightly affected with nematodes and Rhizoctonia root lesions (see Pl. III, fig. 1–*B*), grown in soil treated with only 1,000 c. c. of boiling water. *C*, A very poor stand of stunted and yellowed plants, the roots of which were found badly infected with nematodes and Rhizoctonia (see Pl. III, fig. 1–*C*), grown in untreated infested soil. Note the increase in size, vigor, and number of plants resulting from the hot-water treatments. This may be due not only to reduction of root parasites, but in part also to a stimulating effect from changes of the soil, due to the heating.

TOMATO PLANTS GROWN IN 8-INCH POTS OF TREATED AND UNTREATED INFESTED SOIL OF EXPERIMENT SERIES I, TAKEN (FIG. 1) TWO WEEKS AFTER PLANTING AND (FIG. 2) AT THE END OF THE EXPERIMENT.

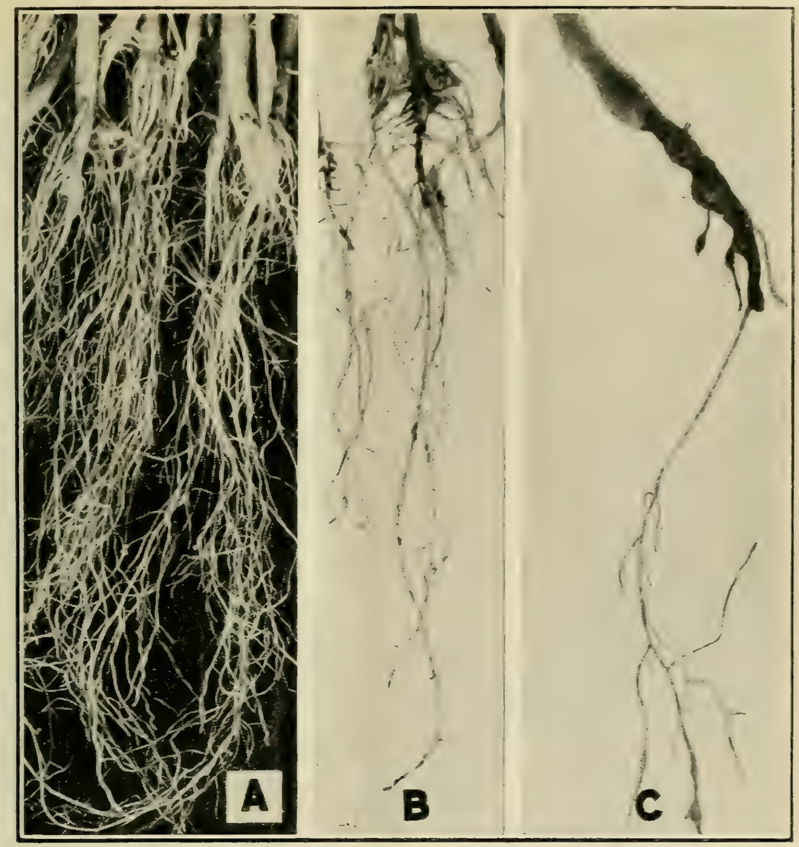

FIG. 1.—ROOTS AND STEMS OF TOMATO PLANTS TAKEN FROM 8-INCH POTS OF TREATED AND UNTREATED INFESTED SOIL, SHOWN IN PLATE II, FIGURES 1 AND 2.

A, Large disease-free root systems of plants grown in a pot treated with 3,000 c. c. of boiling water (98° C.) (natural size); *B*, smaller root systems of plants grown in a pot receiving 1,000 c. c. of boilng water (natural size). Note occasional nematode galls on lower part of roots and a small number of dark Rhizoctonia root lesions. *C*, Roots and stem of plant from check pot (enlarged 2½ times). Note large galls on stem and old part of root system and small galls on younger, newly formed root system. It should also be noted that the lower part of the taproot and practically all of the secondary roots have been destroyed by the pathogenes.

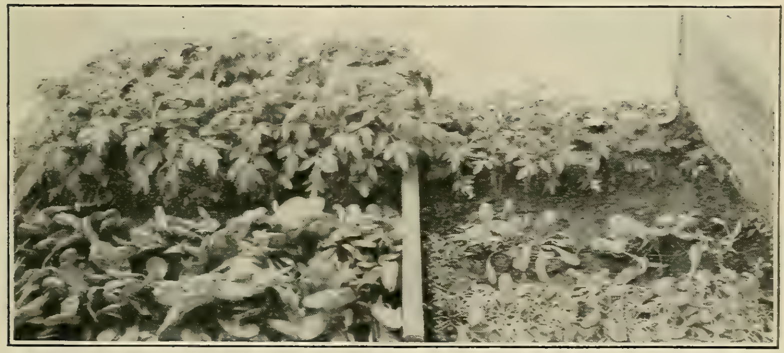

FIG. 2.—BENCH SECTIONS NO. 3 (LEFT) TREATED WITH 17,000 C. C. (3.6 GALLONS) PER CUBIC FOOT OF SOIL OF BOILING WATER (98° C.) AND NO. 4 (RIGHT) UNTREATED CHECK, EXPERIMENT SERIES I.

Note the differences as to number, size, and vigor of plants in the two sections. Pronounced differences in the root systems of the lettuce plants taken from these sections are shown in Plate IV, figure 1.

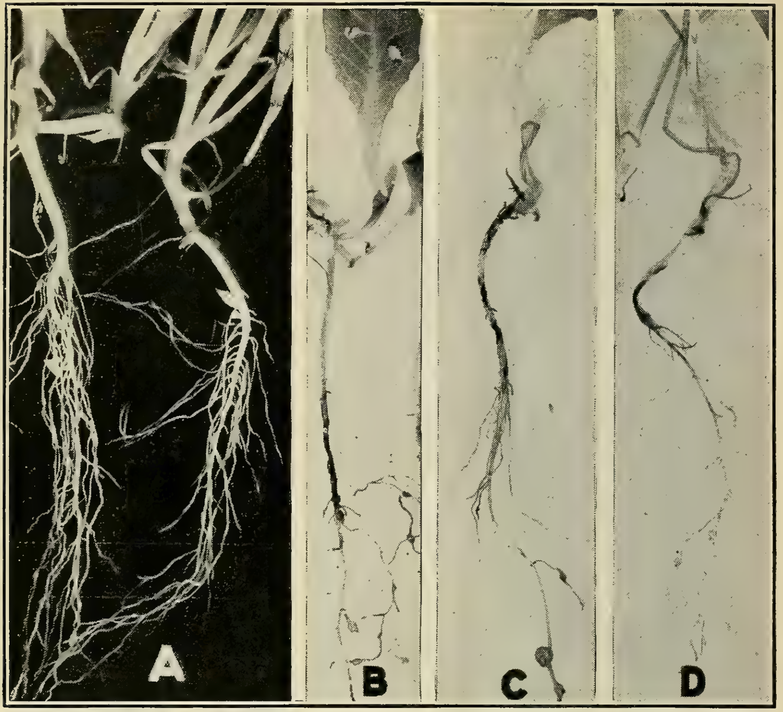

FIG. 1.—LETTUCE PLANTS FROM BENCH SECTIONS NOS. 3 AND 4, SHOWN IN PLATE III, FIGURE 2.

Note (*A*) the white, healthy, vigorous root systems from plants grown in treated section No. 3, as compared with (*B*, *C*, and *D*) the nematode infe4ted and blackened, Rhizoctonia-diseased roots from untreated section No. 4.

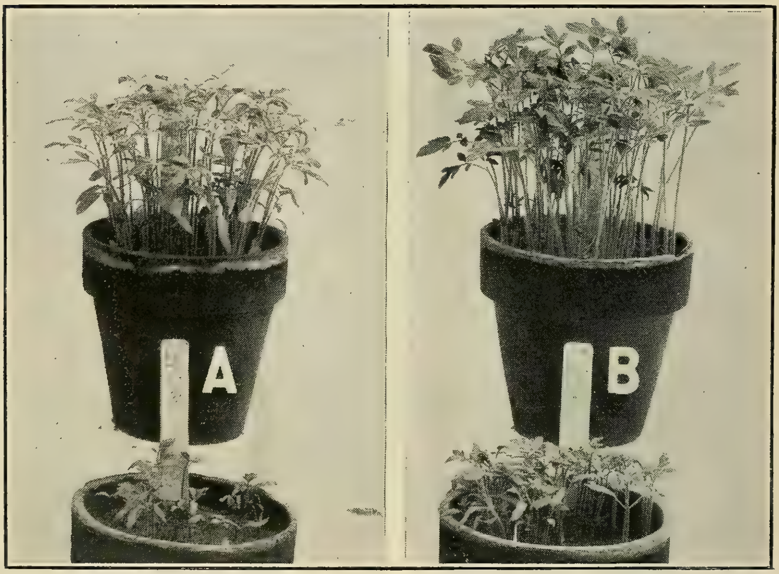

FIG. 2.—TOMATO PLANTS GROWN IN 4-INCH POTS OF (A,) TREATED AND UNTREATED INFESTED SOIL AS COMPARED WITH (B,) TREATED AND UNTREATED FRESH GREENHOUSE SOIL, EXPERIMENT SERIES II.

Note the pronounced differences in size, vigor, and number of plants between the front check pot and the back treated pot. For details of results, see the text.

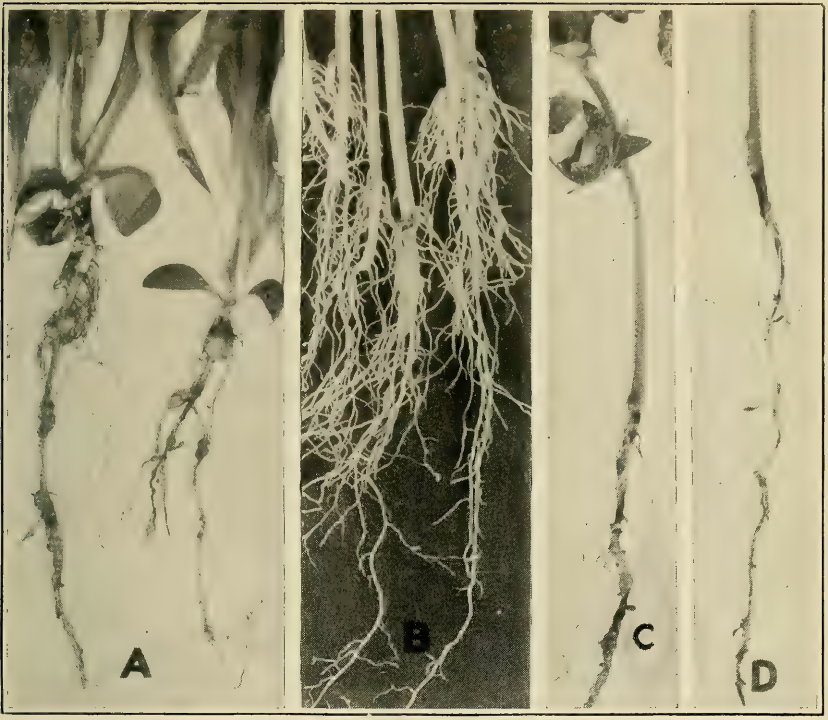

FIG. 1.—LETTUCE AND TOMATO PLANTS FROM 8-INCH POTS OF TREATED AND UNTREATED INFESTED SOIL FROM EXPERIMENT SERIES II.

B, Disease-free root systems of tomato plants grown in pot receiving 3,000 c. c. of boiling water (98° C.), for comparison with *A*, lettuce plants, and *C* and *D*, tomato plants, grown in check pots. Note on the check plants the abundant nematode galls on the roots and stems and the numerous black Rhizoctonia lesions.

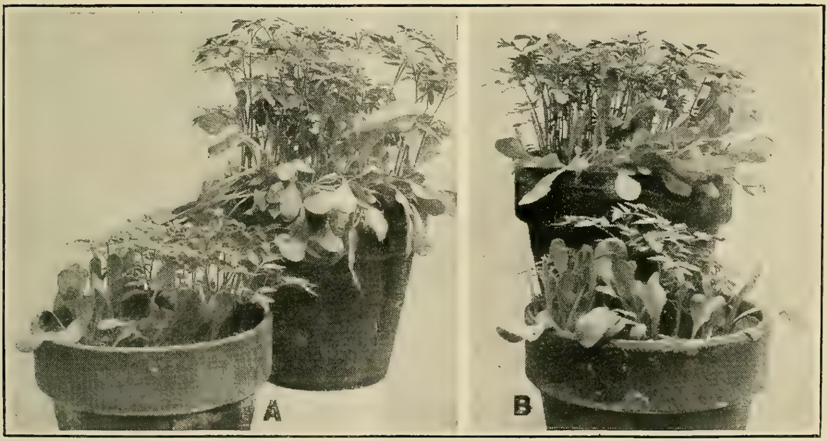

FIG. 2.—TREATED AND UNTREATED 8-INCH POTS OF (A), FRESH GREENHOUSE AND (B), INFESTED SOIL CONTAINING LETTUCE AND TOMATO PLANTS, PHOTOGRAPHED AT THE END OF EXPERIMENT SERIES II.

In the foreground note the smaller size and number of the plants in the check pots as compared with the full stand and larger size of the plants in the pots in the background treated with 3,000 c. c. of boiling water.

The object of using fresh greenhouse soil was to determine, if possible, how much of the increased growth in plants in treated soil was due to the absence of the pathogenes and how much to the chemical or physical effects of the boiling water applied.

For the bench experiment, soil from the previous bench experiment was used, with which was mixed a quantity of soil from the eelworm-infested tomato bench.

TREATMENT OF THE SOIL.

Four-inch pots.—Twelve 4-inch pots were filled with infested soil and treated as follows: Three check pots were immersed in cold water and three each immersed in boiling water at 98° C. for 2½, 5, and 10 minutes, respectively. They were allowed to dry for four days and were then sown to Stone tomatoes.

This experiment was duplicated, using greenhouse soil presumably uninfested and three additional check pots.

Eight-inch pots.—Twelve 8-inch pots were filled with infested soil and treated as follows: Three were thoroughly soaked with cold water and used as checks and three each were treated by the application of 2,000, 3,000, and 4,000 c. c. of boiling water, respectively. All were allowed to dry for four days, and were then sown to Stone tomatoes and Big Boston lettuce, one-half of each pot to each crop.

The experiment was duplicated with greenhouse soil supposedly uninfested, six checks being used instead of three.

Certain of these pots were used to determine the temperatures observed in the soil, the time required to raise the soil to the different temperatures, and the length of time the heat was maintained, the results of which are given in Table VI.

Greenhouse bench.—The bench experiment was an exact repetition of that of Experiment Series I, except as to the quantities of boiling water applied, which in this case were 11,250, 22,500, and 33,750 c. c., respectively, for sections 1, 2, and 3. These quantities were computed as approximately equivalent to 1,000, 2,000, and 3,000 c. c. per 8-inch pot of soil.

In section 3 a record of soil temperatures obtained during the treatment was kept, as in the case of the 8-inch pots. Two thermometers were inserted in the soil in different parts of the bench section to a depth of 3 to 4 inches and the temperatures recorded.

RESULTS.

The details of the results secured from this series of experiments are given in Tables III to VI in the form of germination counts, notes on disease occurrence and on the vigor and size of plants, and temperature records. The experiment was terminated on June 12, and notes on root infections were made as in Experiment Series I.

Photographs were taken to illustrate the more important results secured.

Table III.—*Soil-disinfection tests with tomato plants grown in 4-inch pots, with hot water treatment, in May and June, 1918.*

[Two kinds of soil were used: Soil *A* was nematode and fungus infested; *B* was uninoculated fresh greenhouse soil.]

Kind of soil and treatment of soil-filled pots.	Pot No.	Number of plants.		Results observed on June 12 (end of experiment).										
				Nematode infestation of roots.					Rhizoctonia infection of roots.		Notes on disease, size, and vigor of plants.			
		On May 18.	On June 12.	Severe.	Medium.	Mild.	Total.	Percentage.	Number of plants.	Percentage.	With stem galls.	Damped-off.	Height (inches).	Vigor.[1]
Soil *A*:														
Immersed in boiling water—														
2½ minutes	1	40	41	0	0	0	0	0	0	0	None	None	4 to 5½	HV.
	2	37	37	0	0	0	0	0	0	0	do	do	do	
	3	46	48	0	0	0	0	0	0	0	do	do	do	
5 minutes.	1	47	47	0	0	0	0	0	0	0	do	do	do	HV.
	2	38	38	0	0	0	0	0	0	0	do	do	do	
	3	46	46	0	0	0	0	0	0	0	do	do	do	
10 minutes	1	48	49	0	0	0	0	0	0	0	do	do	do	HV.
	2	51	49	0	0	0	0	0	0	0	do	do	do	
	3	55	55	0	0	0	0	0	0	0	do	do	do	
Check (immersed in cold water).	1	37	33	23	4	6	33	100	30	91	Several	Some	1½ to 2	SY.
	2	38	33	17	10	6	33	100	33	100	do	4	2	
	3	25	15	14	0	1	15	100	15	100	0	5	1½	
Soil *B*:														
Immersed in boiling water—														
2½ minutes	1	51	49	0	0	0	0	0	0	0	None	None	4 to 5½	HV.
	2	70	70	0	0	0	0	0	0	0	do	do	do	
	3	71	67	0	0	0	0	0	0	0	do	do	5½	
5 minutes.	1	51	51	0	0	0	0	0	2	4	do	do	4 to 5½	HV.
	2	55	57	0	0	0	0	0	0	0	do	do	do	
	3	37	34	0	0	0	0	0	0	0	do	do	do	
10 minutes	1	58	50	0	0	0	0	0	2	4	do	do	do	HV.
	2	38	38	0	0	0	0	0	1	3	do	do	do	
	3	50	50	0	0	0	0	0	1	2	do	do	do	
Check (immersed in cold water).	1	47	40	0	0	6	6	15	35	87	1	2	1½	(2)
	2	22	23	0	0	7	7	30	3	13	0	0	2	
	3	36	34	0	0	8	8	23	18	70	0	0	2	
	4	20	21	0	0	11	11	52	16	76	0	0	1½ to 2	
	5	23	24	0	0	12	12	50	10	41	2	4	2½	
	6	19	17	0	0	1	1	6	6	35	0	2	2	

[1] Abbreviations used: HV=Healthy and vigorous; SY=Stunted and yellow.
[2] Much smaller than in treated soil.

DISCUSSION OF RESULTS.

A close study of Table III reveals a striking confirmation of the results secured in the 4-inch pot treatments of Experiment Series I. All treatments completely eliminated nematode infection and damping-off, almost eliminated Rhizoctonia, greatly increased the percentage of germination, and markedly stimulated the growth of the tomato plants. Again, the check plants in infested soil showed severe nematode and fungous infection and were much dwarfed and yellowed. (See Pl. IV, fig. 2.) Some of the plants grown in untreated greenhouse soil, supposedly uninfested, showed mild nematode infestation, while more than half were attacked by Rhizoctonia.

Because of the partial infestation of the greenhouse soil, it was not possible to determine how much of the increased plant growth in the soil treated with boiling water was due to the killing of the pathogenes and how much resulted from the stimulating effect of the heating.

A scrutiny of the results of the 8-inch pot treatments given in Table IV shows a verification of those secured in Experiment Series I; viz, a marked reduction of the diseases in the 2,000 c. c. treatments and their elimination in the pots which received 3,000 c. c. of boiling water (Pl. V, fig. 1), and a considerable increase in the number, size, and vigor of plants in treated pots above that shown in the check pots (Pl. V, fig. 2). As might be expected, the added 4,000 c. c. treatment gave similar results.

Again, on account of the nematodes and Rhizoctonia in the fresh greenhouse soil, no conclusive results were obtained regarding the degree of growth stimulation which might be caused by the heating alone. It may be noted that in general the percentage of germination and the plant growth were larger in the fresh greenhouse soil than in the old infested soil (Pl. V, fig. 2).

The results from the repeated bench experiment, as given in Table V, show only data from tomatoes, since the lettuce was destroyed by mice shortly after the experiment was started. Here, again, substantial confirmation of the results of Experiment Series I was secured. As in Experiment Series I, the treatment approximately equivalent to 1,000 c. c. per 8-inch pot reduced the amount of disease. In the 2,000 c. c. treatment of Experiment Series II only 11 per cent of the plants showed mild root-knot infection, as compared with 96 per cent of more severe root-knot in the check, while the 3,000 c. c. application practically eliminated the trouble.

A study of Table VI, which gives the soil temperature records, shows that in 8-inch pots treated with 3,000 and 4,000 c. c. of boiling water and in the bench section treated at the rate of 7 gallons per cubic foot of soil, all of which treatments killed the pathogenes, a relatively short time was required to raise the soil temperature to the maximum in each treatment and that the soil retained the heat for a strikingly long period. In all cases the temperature was maintained above 60° C. for more than 30 minutes and above 55° C. for 48 to 65 minutes, both temperatures being well above the thermal death point of the root-knot nematode, as determined by the first writer, and presumably above that of the fungi in question.

TABLE IV.—*Soil disinfection tests with tomato and lettuce plants grown in 8-inch pots, with hot-water treatment, in May and June, 1918.*

[Two kinds of soil were used: Soil *A* was nematode and fungus infested; *B* was uninoculated fresh greenhouse soil.]

Kind of plants, soil used, and treatment of soil-filled pots.	Pot No.	Number of plants		Root infection on June 12 (end of experiment).						Plant notes, May 28.	
				Nematode.				Rhizoctonia.			
		On May 18.	On June 12.	Severe.	Medium.	Mild.	Percentage.	Number of plants.	Percentage.	Height (inches).	Disease.
Tomato plants:											
Soil *A*—											
Boiling water poured into pots—											
2,000 c. c.	1	67	66	0	2	15	23	1	1.5	4 to 4½	None.[1]
	2	73	70	0	2	20	27	0	0	4 to 4½	
	3	64	65	0	0	35	54	3	4	4½	
3,000 c. c.	1	65	64	0	0	0	0	0	0	4 to 4½	Do.[1]
	2	70	66	0	0	0	0	0	0	4½	
	3	85	71	0	0	0	0	0	0	4½	
4,000 c. c.	1	70	55	0	0	0	0	0	0	3½	Do.[1]
	2	56	57	0	0	0	0	1	2	3½	
	3	49	45	0	0	0	0	0	0	4	
Check (soaked with cold water).	1	72	40	16	7	17	100	40	100	2 to 3	(2) (3)
	2	50	22	17	3	1	95	20	90	1½ to 2	(4) (5)
	3	57	42	26	10	4	95	40	95	2 to 2½	(2) (3)
Soil *B*—											
Boiling water poured into pots—											
2,000 c. c.	1	87	48	0	0	0	0	0	0	4½ to 5	None.[1]
	2	56	54	0	0	0	0	1	2	4	
	3	60	52	0	0	0	0	1	2	3½	
3,000 c. c.	1	60	68	0	0	0	0	0	0	5 to 5½	Do.[1]
	2	60	73	0	0	0	0	0	0	6 to 6½	
	3	63	61	0	0	0	0	0	0	4 to 4½	
4,000 c. c.	1	57	52	0	0	0	0	1	2	4½ to 5	Do.[1]
	2	48	48	0	0	0	0	0	0	5	
	3	54	51	0	0	0	0	0	0	6	
Check (soaked with cold water).	1	49	30	0	0	2	7	20	66	1½	(6) (7)
	2	32	31	0	0	18	58	27	87	4 to 5	(7) (8)
	3	40	38	0	0	5	13	16	42	3 to 4	(6) (7)
	4	45	22	14	7	1	100	22	100	4	(7) (8)
	5	43	44	0	0	22	50	15	34	4	(7) (8)
	6	42	47	0	0	17	36	4	9	2	(7) (8)
Lettuce plants:											
Soil *A*—											
Boiling water poured into pots—											
2,000 c. c.	1	77	60	0	1	13	23	0	0	3 to 3½	None.
	2	63	73	0	0	13	18	0	0	3 to 4	
	3	50	31	0	0	2	6	3	10	3	
3,000 c. c.	1	45	47	0	0	0	0	0	0	3 to 3½	Do.
	2	66	52	0	0	0	0	0	0	3 to 3½	
	3	64	52	0	0	0	0	0	0	3½	
4,000 c. c.	1	40	48	0	0	0	0	0	0	2½ to 3	Do.
	2	43	38	0	0	0	0	1	2.5	2½ to 3	
	3	37	30	0	0	0	0	0	0	3	
Check (soaked with cold water).	1	45	13	12	1	0	100	10	77	2	(9)
	2	30	22	20	1	1	100	1	4	1 to 1½	(10)
	3	43	26	21	4	0	95	12	46	2	
Soil *B*—											
Boiling water poured into pots—											
2,000 c. c.	1	71	37	0	0	0	0	1	3	3½	None.
	2	77	35	0	0	0	0	3	9	3	
	3	55	46	0	0	0	0	0	0	3	
3,000 c. c.	1	63	51	0	0	0	0	0	0	3½	Do.
	2	66	62	0	0	0	0	0	0	4 to 4½	
	3	49	47	0	0	0	0	0	0	3	
4,000 c. c.	1	40	43	0	0	0	0	0	0	3½	Do.
	2	55	34	0	0	0	0	0	0	3½ to 4	
	3	59	34	0	0	0	0	0	0	4	
Check (soaked with cold water).	1	45	44	0	0	8	18	5	11	2	Do.
	2	32	23	0	0	2	9	23	100	3	
	3	30	30	0	0	5	17	0	0	3	
	4	33	23	20	3	0	100	5	22	3½	
	5	16	13	0	0	7	54	4	31	2	
	6	47	31	0	0	7	22	0	0	1½	

---

[1] Plants vigorous.
[2] Damped-off, few.
[3] Nematode stem galls, many.
[4] Damped-off, many.
[5] Nematode stem galls, few.
[6] Damped-off, 1.
[7] Nematode stem galls, none.
[8] Damped-off, none.
[9] Several plants damped-off and some with stem galls.
[10] No damping-off, but several plants with stem galls.

TABLE V.—*Soil-disinfection tests with tomato plants grown in shallow bench sections, with hot-water treatment, in May and June, 1918.*

[The bench sections were filled with nematode and fungus infested soil thoroughly mixed by sifting.]

Bench section No.	Application of boiling water (at 98° C.).			Total plants.	Root infection on June 13 (end of experiment).							Plant notes, May 28.	
					Nematode.					Rhizoctonia.			
	Total quantity.	Number of doses.	At rate per 8-inch pot.		Severe.	Medium.	Mild.	Total.	Percentage.	Number of plants.	Percentage.	Height.	Vigor.
	C. c.		*C. c.*									*In.*	
1	11,250	1	937	107	0	8	70	78	73	0	0	5	Healthy.
2	22,500	1	1,875	66	0	0	7	7	11	2	3	4	Do.
3	33,750	2	2,812	126	0	0	3	3	2	2	2	4–5	Do.
4 check[1]	....	......	....	102	2	38	58	98	96	2	2	4	(2)

[1] Saturated with cold water.

[2] One plant damped off.

TABLE VI.—*Record of temperatures in hot-water disinfection tests of soil in 8-inch pots and bench sections.*

[Treatments were with boiling water (at 98° C.). Two series of time observations (in minutes) were made, as follows: Series *A*, time required to reach the temperature indicated; series *B*, time during which soil temperatures remained above the points indicated. Temperatures were ascertained by inserting standard thermometers to a depth of 3 to 4 inches in the center of the pots and at two points in the bench section (No. 3).]

Observation data.	Water applied (c. c.).	Pot No.	Thermometer No.	Temperatures (° C.).															
				50	55	60	64	66	70	72	75	76	77	78	79	80	81	82	83
Time, series *A*:																			
8-inch pots	3,000	1	....	....	4	....	....	6	....	7	9	10	....	....	....	....	....	....	....
		2	....	....	5	....	....	6	....	7	7.5	....	....	8.5	9	10	10.5	....	....
		3	....	....	4	....	....	5	....	6	6.5	....	....	7	....	8	9	....	....
	4,000	1	....	....	2.5	....	....	4	....	4.5	5	....	....	6	....	6.5	7	7.5	9
		2	....	....	5.5	....	....	6.5	....	7.5	8	....	....	9	9.5	10	12.5	....	....
Bench section[1]	33,750	....	1	3	....	4	....	....	5	....	6	....	7	....	....	....	....	....	....
			2	7.5	8.5	9.5	13	....	....	....	....	....	....	....	....	....	....	....	....
Time, series *B*:																			
8-inch pots	3,000	1	....	....	....	....	....	33	....	19	9	5	....	....	....	....	....	....	....
		2	....	....	....	....	....	28	....	19	....	13	....	9.5	....	4	....	....	....
		3	....	....	57	....	....	33	....	23	16.5	....	....	11	....	7	....	....	....
	4,000	1	....	....	65.5	....	....	40	....	27.5	22	....	....	14	....	10.5	9	6.5	....
		2	....	....	63.5	....	....	38.5	....	25.5	20	....	....	14	....	8	3.5	....	....
Bench section[1]	33,750	....	1	10.2	61.5	53	41.5	....	....	....	10	....	....	....	....	....	....	....	....
			2	80.5	48.5	36.5	....	....	....	....	....	....	....	....	....	....	....	....	....

[1] The application of hot water to the bench section (No. 3) was at the rate of 3,000 c. c. per 8-inch pot of soil.

SUMMARY.

1. The root-knot nematode (*Heterodera radicicola*), Rhizoctonia species, and *Pythium debaryanum* can be eliminated from soil in 4-inch pots by submersion for 5 minutes in water at 98° C. (208° F.).

2. These organisms can also be killed in 8-inch pots by the application of 3,000 c. c. of water heated to 98° C. (208° F.). This treatment is the equivalent of an application of about 7 gallons per cubic foot of soil.

3. These pathogenes are almost entirely destroyed in 8-inch pots by treatment with 2,000 c. c. of boiling water (5 gallons per cubic foot).

4. In shallow benches an application of boiling water at the rate of 7 gallons per cubic foot of soil resulted in the practical elimination of the parasites.

5. For use in treating seed boxes this method will find an immediate and practical application, particularly in connection with the boys' and girls' garden-club work. The size of the box or flat commonly used is 14 by 30 by 3 inches, and to treat this 4½ gallons of boiling water is necessary.

6. As a further result of these treatments there was in all cases a marked increase in the percentage of germination and in the size and vigor of the plants grown in the treated soil as compared with the checks.

7. The treatments which were effective in killing the pathogenes maintained the temperature of the soil above 55° C. for 30 to 60 minutes, as indicated by a thermometer inserted 3 to 4 inches below the surface of the soil.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 819

Contribution from the Bureau of Chemistry

CARL L. ALSBERG, Chief

Washington, D. C. PROFESSIONAL PAPER March 10, 1920

A PINK YEAST CAUSING SPOILAGE IN OYSTERS.

By Albert C. Hunter,[1] *Junior Bacteriologist, Microbiological Laboratory.*

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PURPOSE OF INVESTIGATION.

At certain periods during the last few years the oyster growers of New England have had difficulty in shipping oysters for long distances without the development of a pink color in the liquor or on the oyster itself. Analyses of shipments showing this color have demonstrated the cause. The organism producing the pink pigment is a yeast-like fungus which grows readily at low temperature, and produces pigment bright enough to be noticed only when the shipment has been in transit three or four days. Oysters which appear to be in good condition when shipped are often found to be pink when they reach their destination.

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[1] The major portion of this investigation was carried on at Brown University, Providence, R. I., under the supervision of Prof. F. P. Gorham, and was submitted to the faculty of that institution in partial fulfillment of the requirements for the degree of doctor of philosophy. During the early part of the investigation valuable assistance was given the writer by Charles W. Parmelee. The work was completed and the report revised in the Microbiological Laboratory of the Bureau of Chemistry. Valuable criticisms and suggestions have been offered by Dr. Charles Thom of that laboratory.

The investigation here reported was undertaken to determine the distribution of this "pink yeast," and to find a suitable method of controlling or preventing its development. Later, the work was extended to cover a more detailed study of the organism itself, including its morphology, physiology, and biochemistry.

While much concerning the pink yeast and its relation to the oyster industry remains to be studied, the data given in this bulletin may help to a better understanding of the cause of the color, the distribution of the organism, its control, and some of its physical and chemical properties.

HISTORICAL REVIEW.

The true yeasts, Saccharomycetes, and the pseudo yeasts, or Torulaceæ, are widely distributed, and have been isolated from many sources. L. van der Hulle and H. van Laer (1890) isolated a pink yeast from Belgian beer. M. Ward (1892) studied a pink yeast which was an alien organism in ginger beer yeast. Kramer (1891) obtained a pink yeast-like form from must fermentation, while V. Peglion (1895) and E. Kayser (1890) also studied pink yeasts from must fermentation. R. Demme (1890) studied and described a pink form from milk and cheese, and pink yeasts from milk and butter have also been described by Krueger (1892) and R. Reinmann (1900). B. Fischer and K. Brebeck (1894) describe pink yeasts from the stomach of a patient suffering from gastric fermentation, also a pink yeast from samples of sea water south of the Azore Islands.

The opinion that Torulaceæ are merely stages in the development of other fungi has been expressed by many workers, notably by Hansen (1898). E. Klein and N. Gordan (1912) claim that a certain pink yeast originates in a rust infecting the Canada thistle, *Puccinia suaveolens.* On the other hand, R. Meissner (1899) has shown differences between the budding Torula forms and the budding cells of the fungus causing peach leaf curl, *Exoascus deformans.* It is claimed by Laurent (1889) that the budding spores of *Cladosporium herbarium* become pink yeasts. The earliest attempt to study these pink or red yeasts was made by F. A. Janssens and A. Mertens (1903) with an organism described as a "red Torula." Such forms, which have been known for a long time, were first described by Fresenius (1850) as *Cryptococcus glutinis.* Later Schröter and Cohn (1872) grouped the pink yeast with the Saccharomycetes, but Hansen has shown that *Cryptococcus glutinis* comprises several species and can not be included in the Saccharomycetes. Hansen (1902) and P. Lindner (1887) were unable to see any sporulation in the red budding fungi, and Elfving (1886) also studied a pink yeast which did not form spores. A. P. Swan (1896) described a red budding fungus in which he claims to have observed sporulation, but J. Chr. Bay (1896) disputed this in a subsequent publication.

Although frequent mention has been made in various trade journals of the occurrence of the pink color in oysters, no detailed study of the relation of the pink yeast to the oyster industry has been published thus far. Bates and Round have submitted to the Bureau of Chemistry a preliminary report on the occurrence of a pink yeast in oysters during the fall of 1914. Based upon their report, a statement was made in the Report of the Chemist[1] that "It was discovered that a yeast was the probable cause of the reddening which affected thousands of gallons of oysters during the past season."

From the foregoing paragraphs it is evident that these pink yeasts are widely distributed in nature. Owing to a lack of adequate description of these forms, no attempt has been made to identify the organism reported here with any of the forms mentioned other than that they all belong to the same large group of Torulæ.

DISTRIBUTION OF THE PINK YEAST.

After the cause of the color had been found to be a pink yeast the next thing undertaken was a study of the distribution of the organism in the oyster house, in oysters, in surface and deep water samples from Narragansett Bay, and in mud samples taken from the oyster beds. If the distribution was limited to the house, the solution of the problem was simple, consisting merely of finding some suitable method of removing the infection from everything with which the oysters came in contact. If, on the other hand, the habitat of the yeast extended to the water and mud on the oyster grounds, the problem became more complex, with less prospect of eliminating the trouble. An examination was first made of the oyster house and of the utensils in and about the house. Later oysters taken from the decks of the boats were examined before they had entered the house, and finally numerous samples of water and mud were analyzed for the presence of the yeast.

Culture media.—After several preliminary experiments with special culture media of various kinds it was decided that satisfactory results would be obtained with dextrose agar and dextrose broth. These media, upon which the yeast grows abundantly, have been used throughout the work. The agar and broth were prepared according to the directions given in the Standard Methods of Water Analysis of the American Public Health Association. Beef extract, peptone, and pure dextrose were used, and the reaction was adjusted to +0.5 Fuller's scale. One per cent of dextrose has been found sufficient.

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[1] U. S. Dept. Agr. An. Repts., 1915.

IN AND ABOUT THE OYSTER HOUSE.

METHOD OF EXAMINATION.

Large swabs of cotton on wooden rods were made and sterilized and kept in large jars plugged with cotton. A swab was dipped in dextrose broth until thoroughly wet, and then the moistened swab was rubbed lightly over the area under examination. The swab was then returned to the tube of dextrose broth, marked with the necessary data, and returned to the laboratory. Immediately on arriving at the laboratory the dextrose broth tubes in which the swabs were placed were incubated at room temperature (21° to 25° C.) for 12 to 24 hours, after which the broth was plated out in the proper dilutions on dextrose agar. The plates were incubated at room temperature for 7 days, being examined daily for the presence of pink colonies. Whenever a pink colony was found it was taken from the plate with a sterile needle and transferred to an agar slant. At the same time a smear was made for microscopic examination. The colonies are very characteristic, both in color and in general appearance, and can be recognized without difficulty. A smear made from each suspected colony was examined, however, in order to avoid error in recording results.

RESULTS.

In the tables which follow letters have been substituted for the names of boats, while the areas from which samples were taken are designated by numbers.

TABLE 1.—*Results of examination of house and utensils.*

Date.	Location examined.	Result.
1916.		
Sept. 7..	Sides and floor of second bin, south side	0
Do..	Dust from floor of fourth bin, south side	+
Do..	Sides and floor of fourth bin, south side	+
Do..	Opening bench in front of bins, south side	+
Do..	Opening bench in front of bins, south side (men working)	0
Do..	Opening bench in front of bins, north side	0
Do..	Shells from bench, south side, that have rubbed around the bench	+
Do..	Oysters from the pile in the bin (outside of shell examined)	+
Do..	Shucked oysters as passed into washroom	0
Sept. 18.	Deck of the steamer A	+
Do..	Deck of the steamer A (men working at the time)	+
Do..	Oysters in shell from deck of the boat (oyster meats examined)	0
Do..	Inside the tub on steamer A	+
Do..	Inside of wheelbarrow 9	+
Do..	Inside of wheelbarrow 3	+
Do..	Oysters in shell from deck of steamer E (oyster meats examined)	0
1917.		
Sept. 4..	Sides and floor of fourth bin, south side	+
Do..	Sides and floor of seventh bin, south side	+
Do..	Opening bench, south side (new boards)	+
Do..	Opening bench, north side (men working)	+
Do..	Sides and floor of fourth bin, north side	+
Do..	Sides and floor of seventh bin, north side	+
Do..	Window sills on the south side	+

Table 1 shows that the pink yeast is widely distributed throughout the oyster house and the adjacent structures, and can be found on the decks of the boats, 73.9 per cent of the locations examined giving positive results. At the oyster house where the investigation was made the oysters are hoisted from the decks of the boats in tubs, then dumped into deep wooden wheelbarrows and carried back along the runway to be emptied into the bins within the house. Starting at the bins and the opening benches, the pink yeast was found to be rather abundantly distributed on the sides and floors of the bins. The bins first examined in 1916 had not been used since the preceding April, so that the dust from several summer months had accumulated in them. This dust contained large numbers of the yeasts. Attention was next directed to the wheelbarrows in which the oysters are carried, swabbings from the inside of two of which showed that the pink yeasts are to be found there also. Swabbings made from the tubs in which the oysters are hoisted also showed the presence of the yeasts. Going still further back in the search, an examination of the swabbings made of the decks of the boats showed pink yeasts. Oysters from the decks examined at this time showed no yeasts. In examining the oysters from the decks of the boats, the oyster meats within the shell were analyzed, but the outsides of the oyster shells were examined in the sample taken from the bin within the house. These results show that the oyster house itself and the utensils on the premises are, at least, sources of the infection.

IN OYSTERS.

To ascertain whether or not the oysters already contained the yeasts when taken from the waters of the bay, further analyses were made.

METHOD OF ANALYSIS.

Visits to the docks were made at the time when the steamers were to arrive, and samples were obtained before the work of unloading had begun. A representative sample of 15 or 20 oysters was taken from the middle of the pile on the deck, and transported to the laboratory in a cardboard box. The oysters were scrubbed thoroughly with a stiff brush in warm water and soap. They were then opened aseptically, and 3 oysters placed in a sterile jar with their liquor. In opening the oysters the knife was sterilized with flaming alcohol, and the edge of the oyster shell was passed through the flame before opening. The opened oysters in the jar were vigorously shaken 50 times and dilutions made of the liquor. The proper dilutions[1] were plated on dextrose agar and examined as already described.

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[1] 0.1 cc. and 0.01 cc. were found to be adequate.

Later in the course of the work trips were made to the oyster beds, where the samples were taken just as the oysters were brought out of the water, thus avoiding the contact of the oyster with the deck, which was known to be infected. Such samples, placed in cardboard boxes, were kept in a cool place until they could be taken to the laboratory and analyzed. This was usually several hours later, but, inasmuch as the analysis was qualitative rather than quantitative, the delay has not affected the results.

TABLE 2.—*Analyses of oysters from the bay.*

Date.	Source.	Result.
1916.	Steamer:	
Nov. 12	B	0
Dec. 4	B	0
1917.		
Jan. 8	A	0
Jan. 30	A	1 colony.
Feb. 5	A	0
Feb. 21	E	0
Mar. 1	B	0
Mar. 12	B	1 colony.
Mar. 15	B	0
Mar. 19	C	1 colony.
Mar. 22	A	0
Mar. 26	Schooner from Long Island	2 colonies.
Mar. 29	Steamer D	Do.
Apr. 4	Dredge on A, as taken from water	0
Apr. 12	do	0
Apr. 26	do	0
May 24	Dredge on C, as taken from water	0
May 29	Seed oysters taken back from the shop during winter. Taken from bed 4	0
May 31	Old oysters taken at bed 6	0
June 4	do	0
June 8	do	2 colonies.
June 12	do	Do.
June 14	Oysters taken at bed 2	0
June 21	Old oysters taken at bed 6	1 colony.
June 26	Oysters taken at bed 4	2 colonies.
June 28	do	1 colony.
July 3	Deck of Steamer B	0
July 5	Old oysters taken at bed 5	0
July 9	Oysters taken at bed 2	0
July 11	do	0
July 16	Oysters taken at bed 6	0
July 19	Oysters taken at bed 3	0
July 24	Young oysters clinging to starfish mops at bed 2	0
July 31	do	0
Sept. 13	Oysters taken from bed 4	0
Do	Oysters taken at bed 6	0

RESULTS.

The results recorded in Table 2 show that the pink yeasts may also be found in oysters before they have been handled or brought in contact with infected objects. The number of positive results was not as great in the case of the oyster analyses as in the case of analyses made from the oyster house, only 10 oyster samples of the 38 examined, or 26.3 per cent, showing the presence of the yeasts. There was also a decided difference in the number of colonies to be found on the plates made from samples from the two sources.

In no case were there more than two colonies of pink yeasts on one plate in the oyster samples, while the plates made from swabbings from the oyster house frequently presented a surface actually dotted with the pink colonies. An attempt to determine whether or not the infection was localized and whether oysters coming from particular localities were infected failed. As the table shows, yeasts were recovered from oysters taken from beds 6 and 4, two areas which are widely separated, bed 4 being east of Prudence Island and bed 6 some distance west of the island. No relation between the season of the year and the presence of the yeasts could be found, positive results being obtained in midwinter as well as in midsummer. It is interesting to note that oyster samples taken from the deck of a schooner from Long Island on March 26 before these oysters had ever been in the waters of Narragansett Bay showed the presence of yeasts. It may be concluded from Table 2 that the oysters are infected before they reach the city, but a comparison of the results in Table 2 with those in Table 1 shows that the chance of infection is far greater in the house than down the bay.

IN WATER.

To determine whether or not the pink yeasts were to be found floating in the water of the bay or whether they were in the mud and soil on the bottom, analyses of surface and deep water samples have been made.

Method of Obtaining and Analyzing Samples.

The surface water samples were collected in sterilized 14-ounce French tincture bottles in the usual manner. After the sample was collected, the bottle was labeled and set in a cool place, to be carried later to the laboratory. The samples were then plated according to the Standard Methods of Water Analysis on dextrose agar, and the plates incubated and examined as described on page 4.

For collecting the deep water samples, which has presented more difficulties, a special apparatus, devised and used by the Rhode Island Shellfish Commission in its investigation of the waters of Narragansett Bay, was employed. It consists of a heavy piece of brass, 20 cm. long by 4 cm. wide and 2 cm. thick. About 2 cm. from the top of the piece of brass is a slit. A knife edge fitted to slide over the back of the apparatus will pass over the opening of the slit. On the front of the brass piece are two clasps for holding a special tube made from an ordinary test tube, which is heated in the flame and drawn out to a capillary point at right angles to the body of the tube; the whole tube is then heated to drive out the air and sealed, forming a partial vacuum tube. The body of the tube is held in the clasps on the apparatus, and the capillary point passes through the slit and extends out in back. When ready to take a sample of deep water, the tube is placed in the clasps as described, and the apparatus, suspended from a strong cord, is lowered to the required depth. A heavy lead weight, which is pierced so that it will slide over the cord, is held in the hand until the apparatus is at the necessary depth. The weight is then allowed to slide down the cord. When it reaches the apparatus it strikes the sliding knife edge hard enough to cause the edge to slide down, breaking the capillary point of the tube. The tube will then fill up with water to about two-thirds of its capacity, and may be lifted up without any further water being taken in. In this manner a sample of from 15 to 25 cc. can be secured from any depth. Samples thus obtained were carried in a specially constructed rack to the laboratory. The tops of the tubes were then broken, precautions being taken to avoid contamination, and the samples were analyzed in the same manner as surface water samples.

TABLE 3.—*Analyses of surface and deep water samples.*

Date.	Bed No.	Samples.		Result.	
		Location.	Number.	Positive.	Negative.
1917.					
Mar. 26	6	Surface	4	0	4
		Deep	9	0	9
Apr. 4	6	Surface	3	0	3
		Deep	12	0	12
Apr. 12	6	Surface	3	0	3
		Deep	12	0	12
Apr. 26	7	Surface	2	0	2
		Deep	10	0	10
Do.	5	Surface	1	0	1
		Deep	2	0	2
May 22	4	Surface	3	0	3
		Deep	11	0	11
May 24	6	Surface	3	0	3
		Deep	8	0	8
May 29	3	Surface	3	1	2
		Deep	8	1	7
May 31	6	Surface	3	0	3
		Deep	6	2	4
June 4	6	Surface	3	0	3
		Deep	8	0	8
June 8	6	Surface	3	0	3
		Deep	8	0	8
June 12	6	Surface	2	0	2
		Deep	6	0	6
1917.					
June 14	2	Surface	3	0	3
		Deep	8	1	7
June 21	6	Surface	3	0	3
		Deep	8	0	8
June 26	4	Surface	3	0	3
		Deep	8	0	8
June 28	4	Surface	3	0	3
		Deep	8	0	8
July 3	1	Surface	3	0	3
		Deep	7	0	7
July 5	5	Surface	3	1	2
		Deep	8	3	5
July 9	2	Surface	3	0	3
		Deep	8	0	8
July 11	2	Surface	2	0	2
		Deep	8	0	8
July 16	6	Surface	4	0	4
		Deep	8	0	8
July 19	3	Surface	4	0	4
		Deep	7	0	7
July 24	2	Surface	4	0	4
		Deep	8	0	8
July 21	2	Surface	3	0	3
		Deep	8	0	8

RESULTS.

The analyses of water samples give a much smaller number of positive results than do analyses of the oysters or swabbings from the oyster house. But 2 positive samples of surface water have been found in the 71 samples examined, or 2.8 per cent, and but 7 positive samples of deep water in the 194 examined, or 3.6 per cent. The great difference in the number of positive samples obtained from the various sources is apparent when the percentages are compared, 73.9 per cent in the house, 26.3 per cent in oysters, 3.6 per cent in bottom samples, and 2.8 per cent in surface samples. In all the positive cases the number of colonies on the plates was very small in comparison with the number found when examining the oyster house. The water of Narragansett Bay may be considered almost a negligible factor in the contamination of the oysters with the pink yeast. Beds 1 and 7 are widely separated, and extend from above Conimicut Point to the lower part of the bay. Hence in Table 3 it may be noted, as in Table 2, that the positive samples were obtained from areas a great distance apart, and no conclusions can be drawn as to the distribution of the organism in particular localities.

A record of the weather conditions and the temperature of the water has been kept, in the hope that some relation might be found between such conditions and the presence of the yeast, but the very small number of positive results obtained and the fact that these positive results were obtained from localities distant from each other has made such data of no value. It may be said, however, that, as far as can be deduced from the data at hand, there is apparently no relation between the tide, wind, and current and the distribution of the pink yeast in the water.

IN MUD.

METHOD OF COLLECTING AND ANALYZING SAMPLES.

Whenever the bottom was soft and muddy it was a simple matter to obtain the sample. A large dredge was dragged along over such bottom, and then hoisted to the side of the steamer, while a small amount of the material was taken from the dredge by means of a sterile spoon and transferred to a sterile glass jar. When the bottom was hard and sandy, a greater length of chain was let out on the dredge and the speed of the boat was slowed down as much as possible. If the dredge was left down long enough there was no difficulty in securing enough of the sand for analysis. The glass jars containing the samples were placed in the refrigerator on the boat until they could be taken to the laboratory. Samples of mud and sand were analyzed according to the usual methods of soil analysis. A small amount of the material, taken from the jar with a sterile spatula, was thoroughly shaken with 10 cc. of sterile water, and dilutions of this mixture were made. Since the examination was not quantitative, no attempt was made to weigh out or measure known amounts of the muddy material. The plate cultures were made as before described, and examined daily.

RESULTS.

In no case was the pink yeast recovered from the 20 samples of mud and sand collected. It may be concluded that the soil on the bottom of the bay is not a factor in the contamination of the oysters with the pink yeast.

A discussion of the distribution of the yeast and its relation to the oyster industry, together with recommendations for its control, is given on page 21.

EXPERIMENTAL PRODUCTION OF PINK COLOR IN OYSTERS.

In order to prove conclusively that the pink yeast is the cause of the pink color in shipments of shucked oysters, several experiments were undertaken to produce the color by the introduction of cultures of the organism into jars of normal oysters.

Two gallons of oysters, obtained in the market, were divided among 9 glass jars. Five cubic centimeter amounts of a pink yeast culture, grown in an oyster broth medium for 4 months, were introduced into 6 of the jars. The remaining 3 jars were held as controls. Two inoculated jars and a control jar were placed in the cold storage at 0.5° C., in the refrigerator at from 8 to 10° C., and directly on the ice at about 5° C. These jars were examined daily, the presence or absence of a pink color noted, and the temperature within the jars recorded. At the end of the first week the oysters in the jars on the ice and in the refrigerator were decidedly pink. There was no pink color in the jars of oysters used as controls. At the end of one month the oysters in the cold storage at 0.5° C. were slightly pink, while the control oysters were not pink. The pink yeast was recovered from each jar which showed a pink color. In each jar, however, the oysters were spoiled and very sour by the time they were pink. The oysters used for the experiment were shucked with their own liquor, and were delivered to the laboratory without being washed. They contained a large amount of dirt and many bacteria in the mucus which, without doubt, brought about the rapid spoilage.

In order to produce the pink color in oysters properly washed and shipped the following experiment was carried out. A trip was made to a near-by city and 3 gallons of oysters purchased at the packing house. These oysters had been carefully shucked and washed in a blower, and then placed in new, clean 1-gallon cans. Into each of two 1-gallon cans of oysters were introduced about 25 cc. of a 10-day oyster broth culture of the pink yeast. The third can was left as a control. The cans were closed and packed in a wooden box with cracked ice, and shipped to the laboratory just as they would be shipped to the retailer. These oysters were 5 days in reaching the laboratory, and when they were received they were light pink in color. The control can was normal. All 3 cans were placed in cold storage, and in 2 days the 2 cans were decidedly pink, the control remaining normal. In this experiment also the pink yeast was recovered from the pink oyster liquid.

These experiments, together with the fact that the pink yeast was isolated from every shipment of pink oysters examined, are good evidence that the pink yeast is, without question, the cause of the pink color in shucked oysters. The experiments have also shown that when oysters are pink they are close to the stage of spoiling, as it takes 5 or 6 days for the color to develop at a temperature of about 10° C. When kept at a temperature as low as 0.5° C. about 1 month is required to produce the pink color, in which time the oysters become decidedly stale.

MORPHOLOGY OF THE PINK YEAST.

Shape and size.—Elliptical. Maximum measures 9.8 by 7 micra; minimum measures 4.1 by 2.8 micra. Average measurement, 6 by 4 micra. No mycelium. Often grouped in gelatinous framework. Granules, fat globules, and vacuoles present. Budding forms common.

Sporulation.—Yeast grown for 1 month on sterilized gypsum blocks and examined at intervals showed no spores, either when unstained or when stained with carbol fuchsin.

Staining reactions.—Stains readily with methylene blue, safranin, or gentian violet. Not acid fast. Staining by Gram's method is very similar to that reported by Henrici (1914). Decolorized with 95 per cent alcohol, the cells are Gram positive, but a few cells in the field are partly decolorized, showing a number of fine black particles in a red matrix. When 30 per cent acid (HCl) alcohol is used the cells are completely decolorized.

CULTURAL FEATURES OF THE PINK YEAST.

Temperature.—Optimum temperature, 22° C. Will not grow at 37° C. Grows at 6° C., but growth not as abundant nor as characteristic as at 22° C.

Dextrose broth.—Growth first appears as precipitate in bottom of tube. Later a ring forms around wall of tube at surface of medium. Precipitate flocculent. No film formation.

Dextrose agar slant.—Growth along the streak, heavy, moist, and glistening. Later growth collects at base of slant in heavy mass. Growth of slimy consistency.

Gelatin stab.—Growth fair. Uniform along the stab. Pigment production not pronounced. No liquefaction.

Dextrose agar colonies.—Visible about third or fourth day. Round, smooth, moist, and glistening.

Litmus milk.—Same as broth cultures. No coagulation nor peptonization.

Blood serum.—Growth moderate. Similar to agar slant. No liquefaction.

Potato.—Growth moderate. Similar to agar slant. No destruction of starch.

BIOCHEMICAL FEATURES OF THE PINK YEAST.

ACID PRODUCTION.

To determine whether or not acid was produced by the pink organism, cultures were made in various carbohydrate media, and titrations made daily. Dextrose, maltose, lactose, raffinose, saccharose, and glycogen broths were used. Of these the first four were prepared according to the standard methods of the American Public Health Association.

Inasmuch as the pink yeast was found growing in and was isolated from oyster liquor which contains a large amount of glycogen, it was thought necessary to test its acid production in this carbohydrate. Owing to the scarcity of glycogen in pure form and to the difficulty in preparing it, a special medium containing glycogen was made. An infusion of oysters was prepared by infusing finely ground oysters over night with double the quantity of water. The mixture was allowed to boil for 2 minutes over the flame, after which it was strained through a cloth. To the resulting oyster infusion 1 per cent peptone was added, and the broth made neutral. As oysters contain glycogen in amounts varying from 3 per cent to 25 per cent of the total solids according to the season, food supply, etc., the broth prepared no doubt contained a fairly high percentage of glycogen. Growth in this oyster broth at room temperature resembles the conditions under which the yeast occurs, and it is of special interest to test for acid production in this medium. All these media were titrated after sterilization and before inoculation. Thereafter titrations of the cultures and controls were made daily for 7 days. The titrations were made against N/20 sodium hydroxid, using phenolphthalein as an indicator.

In addition, acid production was determined in cultures grown anaerobically, in order to approximate the conditions afforded for the growth of the pink yeast in oysters packed in sealed glass jars. The cultures were grown under paraffin oil and titrated daily as described.

In none of the carbohydrate media used was there any acid production by the pink yeast when grown either aerobically or anaerobically.

ALCOHOL, ALDEHYDE, AND ACETONE PRODUCTION.

The production of alcohol in sugar solutions is without doubt the best known of all properties of the yeast plant. Alcoholic fermentations due to the growth of fungi have been known for a long time, and it was because of the alcoholic fermentation of sugars that the true yeasts were given the name Saccharomycetes. One of the distinguishing features of the Torulæ or pseudo yeasts, however, is the fact that they cause alcoholic fermentation to a very slight degree or not at all. In studying the pink yeast, experiments were conducted to determine whether or not this organism produces alcohol in various sugar media.

The pink yeast was grown at room temperature in dextrose, levulose, maltose, lactose, galactose, raffinose, arabinose, saccharose, glycogen, inulin, and dextrin broths for 72 hours with controls. At the end of the incubation period the cultures and controls were attached to a condenser and distilled. The distillate was tested for alcohol, aldehyde, and acetone by routine methods, and no positive results were obtained. Applied to a culture of a known alcohol-producing yeast these methods gave positive tests. The pink yeast does not give the test for alcohol, aldehyde, or acetone when grown under the conditions described, but whether small amounts of these compounds may be formed under other conditions was not determined.

GAS PRODUCTION.

Experiments were also conducted to determine the gas production of the pink yeast. Dextrose, maltose, lactose, raffinose, saccharose, and glycogen broths were prepared as described. Fifteen cubic centimeters of each medium were used in Dunham fermentation tubes. After inoculating with the pink yeast the tubes were incubated, with controls, at room temperature, and for 7 days examined for the production of gas. Cultures were also grown anaerobically under paraffin oil.

In none of the tubes was any gas produced in 7 days. The tubes were reserved for the examination at a later period, and no gas production was observed for 21 days.

ENZYME PRODUCTION.

Enzyme production is a property possessed by many yeasts. Most of the true yeasts produce invertase, which inverts saccharose to dextrose and levulose. Certain yeasts also produce protease and diastase. Experiments were conducted to determine whether or not protease, diastase, invertase, or rennin are produced by the pink yeast.

Protease.—Fifty cubic centimeters of blood serum and milk serum, filtered through a porcelain candle, were prepared, inoculated, and incubated at room temperature for 3 days. For control purposes cultures of *B. proteus*, which is known to produce a proteolytic enzyme, were also made, and flasks of serum which had not been inoculated were likewise incubated with test cultures for controls. At the end of the incubation period the liquid was made faintly acid with acetic acid, and boiled to precipitate the unaltered proteins. These were filtered out, and the filtrate was tested for polypeptids, peptones, tyrosine, and tryptophane with copper sulphate and sodium hydroxid, Millon's reagent and glyoxylic acid.

Diastase.—Tube cultures of the pink yeast were prepared in sugar-free broth. As controls, cultures of *B. subtilis*, which produces diastase, and sterile broth tubes were incubated for controls, and all the cultures were incubated at room temperature for 3 days. A thin starch paste with 2 per cent thymol was prepared, and equal parts of the cultures and the paste were mixed. The mixtures were incubated for 6 hours at 37° C., and then filtered. The filtrates were tested for sugar with Fehling's solution.

Invertase.—In testing for the production of invertase, tube cultures were made of the pink yeast in sugar-free broth as in testing for diastase. Cultures were also made of the *Saccharomyces cerevisiœ*, which inverts saccharose, and uninoculated cultures were incubated for controls. A 2 per cent saccharose solution was made, and 2 per cent phenol added. Equal parts of the cane-sugar solution and the cultures were mixed and allowed to stand for several hours. They were then filtered, and the filtrates tested for reducing sugar with Fehling's solution.

Rennin.—Tube cultures of the pink yeast and of *B. prodigiosus* were prepared in sugar-free broth, and incubated for 3 days with uninoculated cultures for controls. At the end of the incubation period the cultures were heated to a sufficient temperature to sterilize. By means of a sterile pipette 5 cc. of the culture were introduced into each of 3 litmus milk tubes. The litmus milk tubes were placed in the incubator at 22° C., and examined daily for 10 days.

TABLE 4.—*Enzyme production.*

Enzyme.	Organism.	Result.	Enzyme.	Organism.	Result.
Protease	Pink yeast	0	Invertase	Pink yeast	+
	B. proteus	+		*Sacch. cerevisiæ*	+
	Control	0		Control	0
Diastase	Pink yeast	0	Rennin	Pink yeast	0
	B. subtilis	+		*B. prodigiosus*	+
	Control	0		Control	0

The results in the table indicate that no proteolytic, diastatic, nor milk-coagulating enzyme is formed by the pink yeast, but that the yeast does produce invertase which changes saccharose to dextrose and levulose.

INDOLE PRODUCTION.

In order to test for the production of indole by the pink yeast, cultures were grown for 15 days in tryptophane broth at room temperature, with controls, and were tested daily. The tests were made with paradimethylaminobenzaldehyde and hydrochloric acid. No positive tests were obtained.

AMMONIA PRODUCTION.

The power of the pink yeast to reduce nitrates to nitrites and ammonia was tested. The yeast was grown in peptone-nitrate solution for 10 days, and from the fifth to the tenth day the cultures and controls were tested for the presence of nitrites and ammonia. Sulphanilic acid and α-naphthylamin were used in testing for nitrates, while Nessler's reagent was added to the cultures in testing for ammonia.

TABLE 5.—*Production of nitrites and ammonia.*

Organism.	Result.									
	6 days.		7 days.		8 days.		9 days.		10 days.	
	Nitrites.	Ammonia.	Nitrites.	Ammonia.	Nitrites.	Ammonia.	Nitrites.	Ammonia.	Nitrites.	Ammonia.
Pink yeast	+	+	+	+	+	+	+	+	+	+
Control	0	0	0	0	0	0	0	0	0	0

The results of the experiments show that the nitrates in the culture medium are reduced to nitrites and ammonia.

PHENOL PRODUCTION.

Cultures were prepared in nutrient broth in flasks containing at least 50 cc. of medium, and were incubated at room temperature for 3 days with controls. At the end of the 3 days 5 cc. of 25 per cent sulphuric acid were added to the culture, and the mixture was distilled. The distillate was tested with Millon's reagent, ferric chlorid solution, and bromin water. Both the test and control cultures gave no indication of phenol.

PIGMENT PRODUCTION.

When grown under favorable conditions, the yeast produces abundant pink pigment. The most abundant pigment production is obtained when the yeast is grown upon solid sugar media at room temperature. The pigment is also produced in liquid media, but in much smaller quantity than on solid media. When grown at refrigerator temperature no pigment is produced until the fourth or fifth day, and then only a very slight amount. The pigment is not red or rose-colored, as the name "red Torula" or "red yeast" often given to the organism by investigators would indicate, but is more nearly the color of the ordinary pink coral. Its color matches the Orange Red Tint No. 1 of the Bradley educational colored papers. Chapman (1916), who studied the coloring matter of "red Torulae," has found it to be a substance similar to carotin. In the present investigation of the pigment of the yeast an attempt has been made to determine first a method of dissolving it, and, second, its solubility in various substances. After several experiments with different methods the following manner of dissolving the pigment has been found most productive of results. The yeast was grown on large agar slants for 3 days at room temperature, at the end of which time the growth was transferred to a small mortar and thoroughly ground with fine sand to break the yeast cells. After grinding with the sand the mixture was kept at about 40° C. until completely dried, and then ground again with the solvent to be tested. The mixture was filtered, and if the pigment was soluble the filtrate obtained was of a clear pink color.

Using this method, it has been found that the coloring matter is insoluble in hot and cold water, is slightly soluble in alcohol and carbon disulphid, somewhat more soluble in chloroform, and very soluble in ether. As such solutions of pigment slowly lose their color upon standing in the light, at the end of 2 weeks the chloroform and alcohol solutions were colorless. Ether solutions left standing in the light for 1 month are completely decolorized.

PHYSICAL FEATURES OF THE PINK YEAST.

RELATION TO OXYGEN.

Five methods were used in studying the growth of the pink yeast under anaerobic conditions.

Method 1 (*Hesse's method*).—Stab cultures were made in dextrose agar, choosing for the purpose a straight tube containing a deep column of medium and thrusting the inoculating needle to the bottom of the tube. A layer of sterile paraffin oil, 1 to 2 cm. deep, was poured on the surface of the medium, and the culture was incubated at room temperature with a control tube of agar which had not been inoculated.

Method 2.—A tube of agar was liquefied by heat, poured into a sterile Petri dish, and allowed to solidify. The surface of the medium was inoculated with the pink yeast in one spot only. A cover slip was taken from a jar of alcohol with sterile forceps, and the alcohol burned off in the flame. The sterile cover slip was lowered on the medium over the inoculated spot, carefully excluding air bubbles, and was then pressed down firmly with the points of the forceps. This plate was incubated at room temperature with a control plate.

Method 3 (*Roux's physical method*).—Tube cultures of liquid media were prepared as usual, and some of the inoculated media was aspirated into capillary pipettes. The ends of the capillary pipettes were carefully sealed in the flame, and the pipettes with their controls were incubated at room temperature.

Method 4 (*Buchner's method*).—Tube cultures were prepared as already described. Ten cubic centimeters of "acid pyro" solution were placed in a large Buchner's tube, and to this was added 1 cc. of N/10 sodium hydroxid, or 2 cc. of N/20 sodium hydroxid. The inoculated tube was placed inside the Buchner tube, and the mouth of the tube fitted tightly with a moistened rubber stopper. The tubes were incubated with controls.

Method 5 (*Wright's method*).—After tube cultures had been prepared as usual, the portion of the cotton-wool plug projecting above the mouth of the tube was cut off with scissors, and the plug pushed into the tube for a distance of 2 or 3 cm. By means of a pipette about 1 cc. of 10 per cent aqueous solution of pyrogallic acid was dropped onto the plug. It was absorbed immediately. By means of another pipette, an equal amount of N/10 sodium hydroxid was introduced, and the mouth of the tube quickly closed with a tightly fitting rubber stopper. The tube was incubated at room temperature with a control tube.

All these tubes were examined daily for 7 days, and the growth of the yeast recorded (Table 6).

TABLE 6.—*Anaerobic growth of the pink yeast.*

Method.	Organism.	Growth.						
		24 hours.	48 hours.	72 hours.	96 hours.	120 hours.	144 hours.	168 hours.
1	Pink yeast	+	+	+	+	+	+	+
	Control	0	0	0	0	0	0	0
2	Pink yeast	+	+	+	+	++	++	++
	Control	0	0	0	0	0	0	0
3	Pink yeast	+	+	+	+	+	++	++
	Control	0	0	0	0	0	0	0
4	Pink yeast	+	+	+	+	+	++	++
	Control	0	0	0	0	0	0	0
5	Pink yeast	0	0	0	+	+	+	+
	Control	0	0	0	0	0	0	0

In the table a double plus sign (++) indicates a very abundant growth of the yeast. It is evident that the pink yeast grows readily when oxygen is excluded from the culture. The production of the pigment is in no way affected by the absence of oxygen.

RELATION TO TEMPERATURE.

As has been stated previously, the pink yeast grows best at room temperature (21° to 25° C.), whereas no growth occurs in the 37° C. incubator. The yeast grows but sparsely at refrigerator temperature (6° C.), and with but slight pigment production, the bright pink color appearing only after several days.

Thermal Death Point.

In view of these facts, it was assumed that the thermal death point of the yeast would be low, so that in determining this temperature the start was made at 36° C. The method used was taken from the Standard Methods of Water Analysis of the American Public Health Association. A 48-hour-old culture grown at room temperature was used.

Table 7.—*Thermal death point of the pink yeast.*

Temperature.	Result.							Temperature.	Result.						
	1 day.	2 days.	3 days.	4 days.	5 days.	6 days.	7 days.		1 day.	2 days.	3 days.	4 days.	5 days.	6 days.	7 days.
°C.								°C.							
48	+	+	+	++	++	++	++	58	0	0	+	+	+	+	++
50	0	0	+	+	++	++	++	60	0	0	+	+	+	+	++
52	0	0	+	+	+	+	+	62	0	0	+	+	+	++	++
54	0	0	+	+	+	+	+	64	0	0	0	0	0	0	0
56	0	0	+	+	+	+	+	66	0	0	0	0	0	0	0

In Table 7, + indicates that the yeast was living in the tubes after exposure to the heat, and 0 indicates that there was no growth.

The temperature of 36° C., at which the experiment was started, was very much too low, and the heat had no apparent effect on the yeast up to 48° C. The temperatures below 48° C. are therefore omitted from the table, as are the records of the control tubes in which there was no growth. By raising the temperature of the bath 2 degrees at a time it has been found that the thermal death point of the yeast is 64° C. There is apparently no relation between the optimum temperature of the yeast and its thermal death point. In working on the thermal death point of the true yeast used in bread making, Wells (1917) found that the thermal death point of yeast in bread making is approximately 68° C., slightly higher than was found by the author to be the case with the pink yeast.

RELATION TO REACTION OF MEDIUM.

Experiments on the relation of the growth of the pink yeast to the acidity or alkalinity of the culture medium were conducted to determine the limits of alkalinity or acidity at which the yeast would grow; also to find the optimum reaction. Dextrose broth was prepared, and divided into 60 cc. portions. The various portions of media were titrated, and the reactions corrected, so that amounts of media were obtained with titre varying from —9 per cent alkaline, to +10 per cent acid.

Each portion of the different media was titrated after sterilization, and the titre recorded. The tubes were then inoculated with the pink yeast, incubated at room temperature with control tubes of the same reaction, and examined for 7 days. The growth in each tube was recorded.

TABLE 8.—*Relation of growth of the pink yeast to reaction of the medium.*

Reaction.		Growth.						
Before sterilization.	After sterilization.	24 hours.	48 hours.	72 hours.	96 hours.	120 hours.	144 hours.	168 hours.
− 1	− 0.8	+	+	+	+	++	+++	+++
Neutral.	+ 0.3	+	++	+++	+++	++++	++++	++++
+ 1	+ 1.0	+	+	++	+++	+++	++++	++++
+ 2	+ 2.0	+	+	++	++	+++	+++	++++
+ 3	+ 2.8	+	+	++	+++	+++	++++	++++
+ 4	+ 3.9	+	+	+	+	+	+	+
+ 5	+ 4.8	+	+	+	+	+	+	+
+ 6	+ 5.6	+	+	+	+	+	+	+
+ 7	+ 7.0	+	+	+	+	+	+	+
+ 8	+ 7.7	+	+	+	+	+	+	+
+ 9	+ 9.2	+	+	+	+	+	+	+
+10	+10.5	0	0	+	+	+	+	+

The terms used in describing the growth in Table 8, which are comparative only, are as follows: Very slight to slight (+); fair to very fair (++); good to very good (+++); excellent to heavy (++++). No growth appeared in any of the control tubes. Nor did growth occur in any medium the reaction of which was less than − 0.8. The growth in the acid media was very slight in the cultures which contained acid to a greater extent than 2.8 per cent. The best growth was obtained in media the reaction of which was between +0.3 and +2. In the cultures the reaction of which was +10.5 the growth was barely discernible, and this may be taken as the limit of acidity.

RESISTANCE TO DESICCATION.

Yeasts, in general, are very resistant to drying, and this has been found to be the case with the pink yeast. Pasteur (1879) studied a yeast which continued to grow after being dried for 1 year.

The pink yeast was dried on glass rods in a specially constructed drying-box. This consisted of a wooden box, the cover of which was perforated. Each one of the holes in the cover of the box was plugged with cotton, and the whole apparatus was sterilized in the autoclave at 15 pounds for 15 minutes. Corks which would fit the holes in the cover of the box were selected, and small glass rods were inserted in the corks. These were sterilized in the autoclave also. Forty-eight-hour-old cultures of the pink yeast were made in dextrose broth. The sterile rods were dipped in these cultures, and the rods, with some of the culture adhering to them, were suspended in the sterilized box. Each day one of the rods was removed from the box, and the yeast which was dried on it washed off in dextrose broth. As each rod was taken from the box the hole was plugged with a sterile cotton plug. The tubes of broth in which the dried rods were washed were incubated at room temperature, and observed for the growth of the yeast.

Up to July 1, 1918, the yeast was recovered in pure culture from rods suspended in the drying-box for 100 days. The fact that drying under atmospheric conditions apparently has no effect on the viability of the pink yeast helps to explain why the yeast, after being dried in oyster bins, etc., for several months, will readily grow when placed in a favorable environment.

RESISTANCE OF THE PINK YEAST TO DISINFECTANTS.

Early in the study of the pink yeast an attempt was made to find a disinfectant with which the infected objects in the oyster house could be washed as a method of controlling the development of the yeast. It was necessary to use a chemical which would in no way be injurious to the oysters should it come in contact with them, or harmful to the consumer in case such oysters were eaten.

Chemicals employed in the disinfection of water, such as calcium hypochlorite, or bleaching powder, and copper sulphate, were first used. Neither of these proved efficient in dilutions such as it was feasible to use. Since the yeast was known to be surrounded by a capsule, probably of a lipoid nature, soap and soapine solutions were tried, in the hope of breaking the capsule and thus killing the yeast. When this failed, copper sulphate was mixed with the soap solution in the belief that the soap might break the capsule and allow the copper sulphate to act. This treatment, however, had no effect on the viability of the yeast. A coal-tar disinfectant in a dilution of 1 to 1,000 parts was not effective, and sodium sulphite and copperas in low dilution were also found to be without effect. Formalin, which was not used at first because of its odor and the fact that molds often grow readily on it, was finally resorted to. It was found that formaldehyde gas present in 1 to 2,500 parts of water quickly kills the yeast.

In testing the effects of disinfectants on the yeast, the following method was employed: The yeast was grown in 9 cc. amounts of dextrose broth for from three to five days. The disinfectant to be tested was diluted in such a manner that 1 cc. added to the 9 cc. of culture would give the required dilution. In the case of calcium hypochlorite the amount of available chlorin was first determined, and dilutions prepared which contained known amounts of the chlorin. When testing formalin, dilutions were made from the commercial 40 per cent solution, and the amount of formaldehyde gas in the final dilution was computed. The cultures to which the disinfectant had been added were set aside for known lengths of time;

then subcultures were made on dextrose agar slants. These agar cultures were examined daily for the growth of the yeast.

After it was found that formaldehyde, 1 to 2,500, would kill the yeast in broth cultures, this disinfectant was applied to the oyster house. Early in the morning the bins and benches of the opening house were swabbed, and the pink yeasts were recovered from the swabs. The bins and benches were then scrubbed thoroughly by means of brooms and running water from a hose. Following the scrubbing the woodwork was washed down with formaldehyde solution, and the bins left unused during the day. Later in the afternoon the bins and benches were swabbed again, and no pink yeasts were obtained.

It is apparent that if this procedure is followed the principal source of contamination can be removed. It is well to leave the formaldehyde solution on the woodwork overnight or during the entire day. The same procedure may be followed in washing the tubs, wheelbarrows, and other contaminated objects in and about the oyster house.

DISCUSSION OF RESULTS.

In discussing the relation of the pink yeast to the oyster industry it will be well to consider the method of handling the oysters in preparing them for shipment, as practiced in most of the establishments in Rhode Island where this study was conducted, to note the possibilities of contamination with the pink yeast in the process, and draw some conclusions from the data already collected as to the source of the contamination.

The oysters are caught in large dredges and dumped on the deck of the boat, after which they are shoveled back along the deck to a large pile amidship. The day's catch of oysters is taken to the oyster house, and unloaded by shoveling the oysters into wooden tubs in which they are carried back into the house and dumped into bins. The oysters are opened into metal dippers and taken to the washroom to be cleansed and iced for shipment. They are first washed on a skimmer with fresh water from a hose, then put into tubs of salt water for 15 minutes, at the end of which time the salt water is replaced with fresh water, and a piece of ice added. When the oysters are thoroughly chilled they are washed on a second skimmer with salt water. The oysters, thus washed, are measured into 1-, 2-, or 5-gallon cans, and covered with a tight-fitting tin cover which is not, however, air-tight. These cans, which are cylindrical, are packed in square wooden boxes of the proper size to hold the can, leaving a space in each corner which is filled with cracked ice. The cover of the box is nailed on, and the oysters thus packed are shipped.

As stated elsewhere (page 1), oysters packed in this way and sent for long distances are often pink when they reach their destination.

The possibilities of contamination in the process of handling just described may now be considered. Disregarding, for the moment, the fact that the oysters may contain the yeasts when taken from the beds, it may be noted that they are immediately brought in contact with the deck of the boat, which is known to be infected. This, then, is one possibility of contaminating the outside shell of the oyster. Later the oysters are placed in tubs, wheelbarrows, and bins which are also known to be infected, presenting further opportunities for contamination. From the time that the oysters are taken from the water until they are opened in the oyster house there is every chance for the outside of the oyster shell to become contaminated with the pink yeast, but practically no chance for the contents of the oyster shell to be contaminated, since the oyster closes its shell and remains tightly closed during the process of handling. On opening the oysters, however, some of the dirt on the outside of the shell is unavoidably transferred to the dipper of opened oysters. Although these oysters are thoroughly washed, small organisms like the pink yeast are not easily washed off, and may be carried along into the shipping cans.

The data collected show that the house, the boats, and the utensils within and about the house are heavily infected with the pink yeast, that no yeasts were found in the mud at the bottom of the bay, and that yeasts were present in a very small number of the water samples. While it is true that some oysters when taken from the water contain small numbers of pink yeast, such oysters are not often found, and it is not probable that this is an important source of infection. The results of this investigation indicate that the source of the trouble lies in and about the oyster house. If measures are taken for preventing contamination there, the trouble from the pink yeast will be eliminated.

The fact that the pink yeast is occasionally found in water samples and on oysters taken from the oyster beds may possibly be explained in the following manner. Every season oysters are brought to the oyster house, where they are culled, and then taken back to the oyster beds. Such oysters are contaminated in the process of handling and no doubt carry back the pink yeast with them to the bay. A further explanation, which seems more probable, is that the shells that are carried down the bay and planted in the summer may be bearers of the pink yeast. After opening the oysters in the oyster house the shells are dumped in a large pile on the adjacent grounds and left there until June or July, when they are taken to the oyster beds and planted in order to give a smooth, clean surface for the oyster spat and also to furnish calcium salts for the growing oyster. These shells are contaminated with the pink yeast after passing through the house, and it is known that the pink yeast grows aboundantly in the shells and in the moisture which collects at the bottom of the pile during months in which they lie in the yard. When these shells are taken to the beds it is probable that large numbers of the pink yeasts are carried with them.

As a method of control it is recommended that all the bins, benches, tubs, etc., be scrubbed thoroughly with water and then washed with a 0.04 per cent solution of formaldehyde gas, which is equivalent to 1 part of formaldehyde to 2,500 parts of water. Such a solution may be prepared by adding 1 part of commercial formalin to 1,000 parts of water. The washing should be done in the fall, before any oysters are brought to the opening house; and bins, benches, tubs, etc., should also be washed several times during the winter whenever convenient.

SUMMARY.

1. The organism causing a pink color in shipped oysters is a yeast-like fungus.

2. This pink yeast was found in large numbers in the oyster house and on the utensils in and about the house. Of the examinations of the house and utensils 73.9 per cent were positive.

3. The yeast was found less frequently in oysters before they were brought to the oyster house. Of the oyster samples analyzed 26.3 per cent were positive.

4. Occasionally the yeast was found in deep and surface water samples from the oyster beds. Three and six-tenths per cent of the deep samples and 2.8 per cent of the surface samples were positive.

5. The yeast was not found in mud samples from the bottom of the bay.

6. The yeast is elliptical, measuring 6 by 4 micra. It reproduces by budding and does not form spores. Staining by Gram's method is peculiar.

7. The yeast grows at room temperature (21° to 25° C.), and does not grow at 37° C. The best medium for its growth is dextrose agar, although it can be grown on gelatin, potato and blood serum, and in broth and milk.

8. The yeast does not produce acid, gas, nor alcohol in carbohydrate media. It inverts saccharose. It does not produce indole nor phenol. It reduces nitrates to nitrites and ammonia.

9. The yeast produces a pink pigment which is insoluble in water, slightly soluble in alcohol and carbon disulphid, somewhat more soluble in chloroform, and very soluble in ether.

10. The yeast grows abundantly in the absence of oxygen. Its thermal death point is 64° C. The limits of alkalinity and acidity for its growth are -0.8 and $+10.5$. It grows best between $+0.3$ and $+2.0$. It resists drying for at least 100 days.

11. Formaldehyde gas, 1 part to 2,500 parts of water (0.04 per cent solution), kills the yeast.

12. The pink yeast belongs to that group of yeast-like forms called Torulæ. Since the complete life cycle of the Torulæ is unknown they are placed among the *Fungi Imperfecti.*

13. The principal source of contamination of oysters with the pink yeast is in the process of handling in the oyster house.

14. The shell pile of the opening house is a favorable place for the yeast to grow, and when the shells are later deposited on the oyster beds they serve to distribute the yeasts in the water.

15. For the purpose of preventing the infection of opened oysters by the yeast, the house and utensils should be washed occasionally through the opening season with a 1 to 2,500 formaldehyde solution (formalin, 1 to 1,000).

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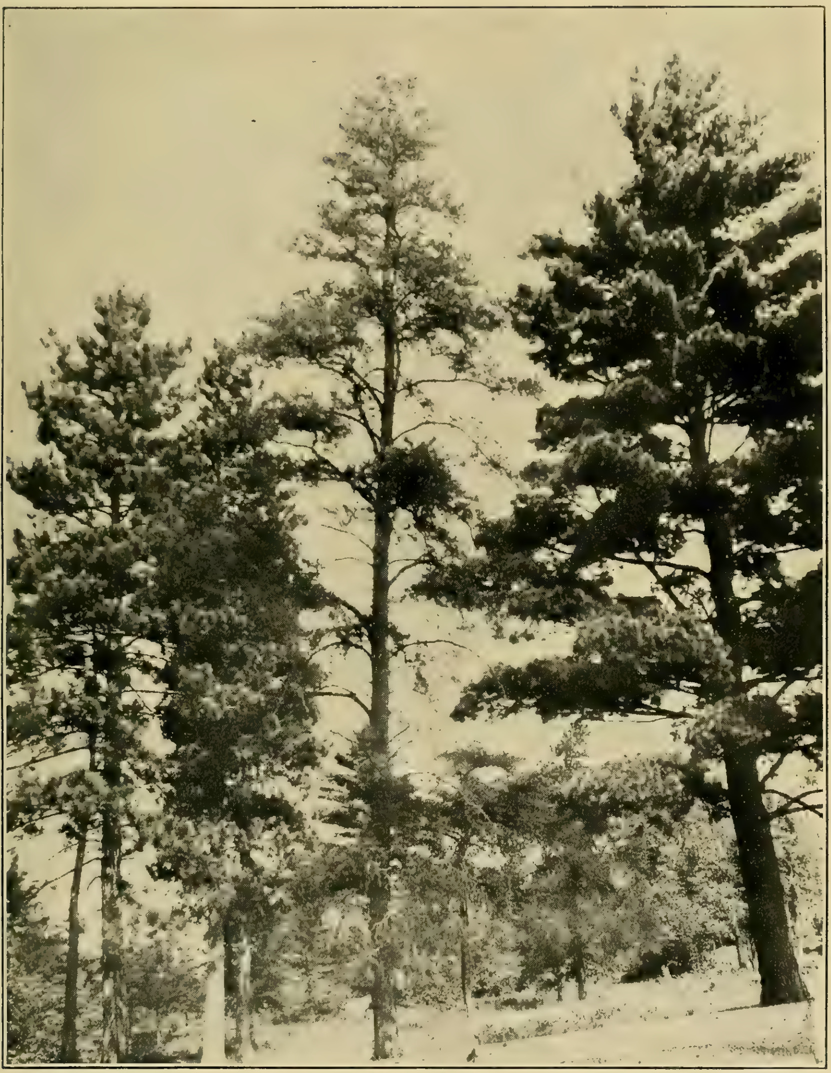

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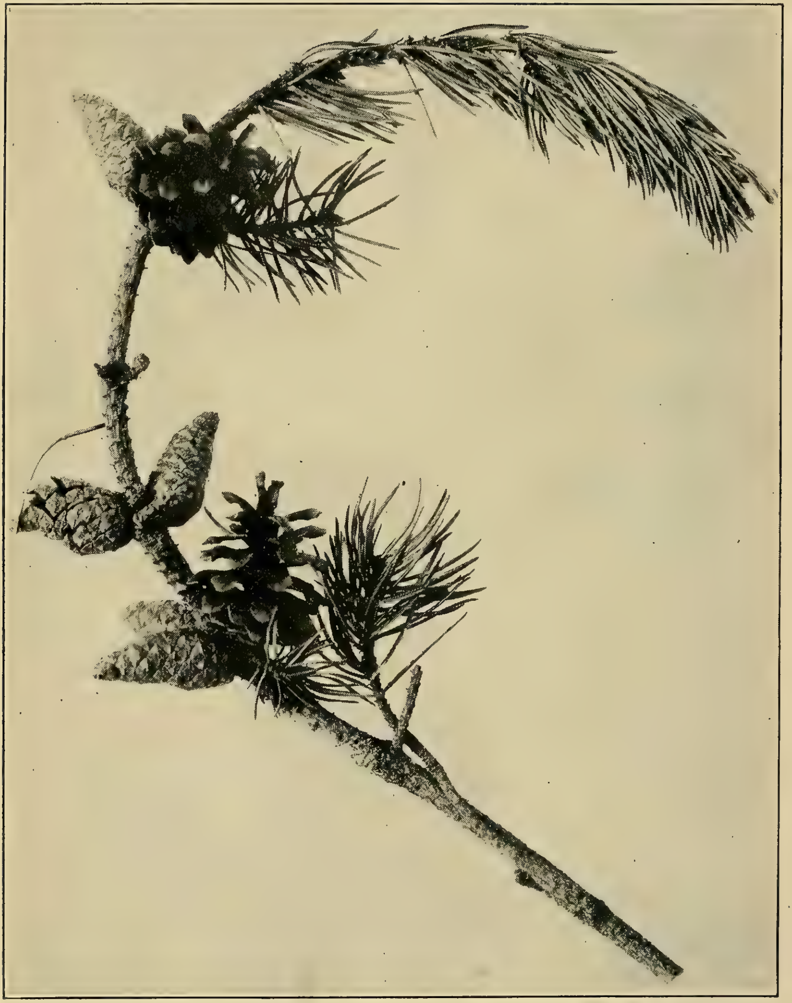
CHARACTERISTIC APPEARANCE OF DENSE-FOLIAGED WHITE PINE ON THE RIGHT, THIN-FOLIAGED JACK PINE IN THE CENTER, AND MEDIUM-FOLIAGED NORWAY PINE ON THE LEFT.



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OPENED JACK PINE CONES, WHICH SHED THEIR SEED SEVERAL YEARS AGO, AND, ON THE SAME BRANCH, UNOPENED CONES CONTAINING FERTILE SEED.

In case of lumbering and fire the latter also open up and shed their seed.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 820

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER May 22, 1920

JACK PINE.

By William Dent Sterrett, *Forest Examiner.*

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INTRODUCTION.

Jack pine[1] is a very frugal tree in its climatic and soil requirements. The northern limit of its natural range is within 1½ degrees of the Arctic Circle and the southern is marked by the southern shores of Lake Michigan. No other North American pine grows naturally so far north and all the others grow farther south. It develops commercial stands and reproduces itself on dry, barren, sandy ridges and plains unsuited to other native trees. The seed germinates more quickly and grows more rapidly in its early years on lumbered and burned-over forest land and on idle, worn-out, cleared land than the other pines occurring within its range. On good soils or on poor soils with a cover of moisture-conserving mulch resulting from forest growth it gives way to longer lived species. The fires which are common on jack pine lands burn off the litter, keep the soil impoverished, and prolong the tenure of jack pine over extensive areas of sandy ridges and plains. There are large areas with poor soil and severe climate, especially in Canada, on which jack pine is the permanent forest growth. It is, therefore, one of the characteristic forest types of the North.[1]

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[1] Jack pine was described under the name of *Pinus divaricata* by Du Mont de Courset in 1802, and a year later by Lambert as *Pinus banksiana* (named after Sir Joseph Banks). From the latter are derived the names Banksian and Banks pine, by which names the tree is commonly known in Europe and in European forestry literature. Lambert's description of it was from a tree planted in England some time in the eighteenth century. The latter name is more widely used than the former, especially in Europe, but by the law of priority in nomenclature *P. divaricata* is the correct name. The term *divaricata*, meaning spreading apart or forked, is especially appropriate for jack pine trees growing in the open. The following common names are applied to the tree in different parts of the country: Scrub pine, general; gray pine, Vermont, Minnesota, and Ontario; jack pine, Lake States and Canada; Princess pine, New Brunswick and Nova Scotia; black jack pine, Wisconsin; black pine, Minnesota; cypress, Quebec to Hudson Bay; Canada horncone pine; check pine (probably a corruption of jack pine); Sir Joseph Banks pine, England; juniper, Canada; Banksian pine, European literature; Labrador pine; and Hudson Bay pine.

In the Lake States jack pine produces chiefly small-sized, knotty lumber, much inferior to that from the Norway and white pines which grow with it. It has, however, good possibilities of profitable utilization for pulpwood, box boards, mine timbers, and other low-grade material. Its rapid growth when young, its good yields per acre on poor land, and the ease which it reproduces itself make it suitable for timber growing on a short rotation.

Jack pine is an important tree for forest management on poor, sandy soils in the region of its natural distribution, and has been successfully planted outside of its natural range in the sand hills of western Nebraska. In the Lake States there are hundreds of thousands of acres of poor, sandy plains-land, impoverished by fires, on which jack pine is a pioneer tree, forming stands by natural reproduction where white and Norway pine have not appeared. These two species come in later with improved soil conditions and under the shelter of the jack pine. Wherever good stands of jack pine can be secured without expense by natural reproduction, that is usually preferable to planting the land with more valuable species at considerable expense and with less certainty of success.

DISTINGUISHING CHARACTERISTICS.

Jack pine has leaves in bundles of two, from ¾ to 1¾ inches long, flat, or slightly concave on their inner surface, and surrounded by a short sheath. The cones are from 1½ to 2 inches long, oblique at the base, sessile, erect, and strongly incurved, with thick, soft scales, armed with minute, incurved prickles which usually fall away. (See Pls. I and II.)

The only other two-leaved pine with which jack pine is likely to be confused is the lodgepole (*Pinus contorta*). The ranges of these two species overlap slightly in central western Alberta.[2] Their leaves are about the same size, and their cones are very similar. The cones of both are curved, but those of jack pine are erect or pointing in the direction of the end of the twig, while those of lodgepole are horizontal or declining, pointing upward or even backward. Jack pine is further distinguished by absence of permanent prickles on the cones. Most characteristic, however, is the position of the cones. In jack pine the cones are subterminal; that is, they grow near the ends of the twigs. In lodgepole pine the cones are lateral; that is, they grow on the sides of the larger twigs.

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[1] The growth, yield, form, and volume tables which are the chief basis for this bulletin were compiled mostly from measurements taken in 1905 on pure, dense, even-aged stands of jack pine in Hubbard County, Minn., by Prof. H. H. Chapman, of the Yale Forest School. The bibliography of data used and reports consulted in the preparation of this bulletin is found on page 34 (appendix).

[2] "The lodgepole is ordinarily confined to higher elevations in Alberta. The upper portions of river slopes will be occupied by lodgepole pine, while the lower slopes and bottom lands may be covered with pure jack pine. As the river is followed into the hills the lodgepole pine gradually replaces the jack pine on the lower levels and finally occupies the whole river bottom and side slopes."—Extract from a letter by R. H. Campbell, Director of the Canadian Forestry Branch.

RANGE.

Jack pine ranges from the southern shores of Lake Michigan to latitude 65° on the Mackenzie River, and from Nova Scotia to the southeastern corner of Yukon Territory and northeastern British Columbia, extending nearly to the foothills of the Canadian Rockies. (See fig. 1).[1] Its range east and west is some 2,500 miles; its north and south extension is 1,600 miles, and averages about 600 miles along any meridan.

In the United States jack pine ranges from western Maine through northern New Hampshire and northern New York, and extends north from northwestern Indiana, northeastern Illinois, through most of Michigan, Wisconsin, and Minnesota. It has also been extensively and successfully planted in the sand hills of western Nebraska. Its occurrence in commercial stands in the United States is limited to certain parts of the Lake States—the Northern Peninsula and the northern half of the Southern Peninsula of Michigan, the northern half of Wisconsin, and the northern half of Minnesota east of the ninty-sixth meridian. In the eastern States it is always a small tree occurring in small, widely scattered groups on sandy barrens.

In Canada jack pine has a much greater range and is of more importance commercially than in the United States. It occurs most abundantly in northern Ontario and Quebec, and in Manitoba, Saskatchewan, and Alberta. In the region west of Lake Winnipeg it reaches a fine development. It is found north of the Saskatchewan River as far west as Fort Assiniboine, and extends north into the valley of the Mackenzie River. It is one of the most abundant trees in the extensive but largely noncommercial forests which cover northern Canada.

GEOLOGY AND CLIMATE OF THE JACK PINE REGION.

The soil in which jack pine occurs in southern Canada, New England, New York, and the Lake States is largely of glacial origin, deposited and spread out by the waters of the melting ice sheet in the last glacial period. To the north, including portions of northern Minnesota and throughout most of its range in Canada, the country is for the most part a region of crystalline rock (granite, gneisses, and schists) severely glaciated and denuded of its mantle of original alluvial soils and only partially covered with thin, light soils of recent origin developed by the weathering of the underlying rock. This is the "Great Laurentian Shield," which comprises over 50 per cent of the area of Canada and extends from the northwest arm of the Lake of the Woods, northwestward and northward to the mouth of the Mackenzie River, the Arctic Ocean, and the mouth of the Winnipeg River, and eastward through Ontario, Quebec, and Labrador. (See fig. 1.) Lakes, rivers, and swamps alternate with low hills and plateaus, which show a remarkably even sky line. The network of waterways extends throughout the region. The soil is found mostly along stream valleys (alluvial), on the southern exposures of ridges (glacial sands

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[1] Botanical range outlined by W. H. Lamb, of the Section of Forest Distribution; commercial range in Canada furnished by R. H. Campbell, Director of the Canadian Forestry Branch; and for the United States by the author.

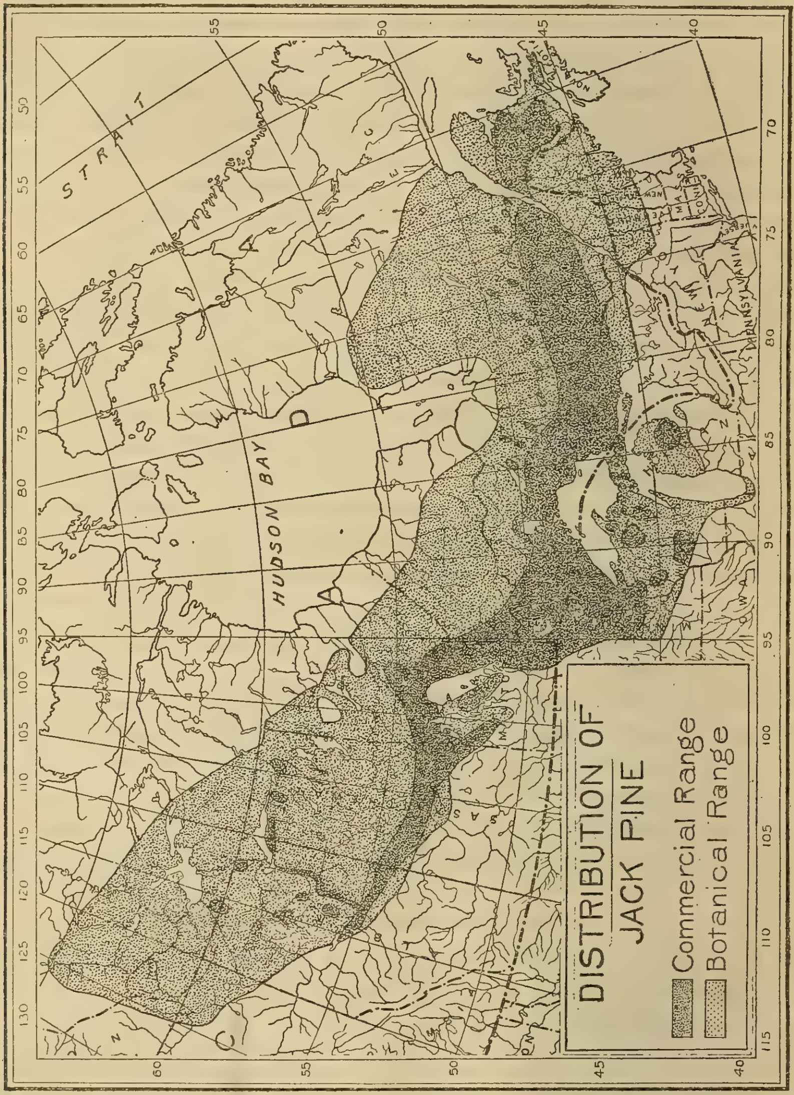

FIGURE 1.

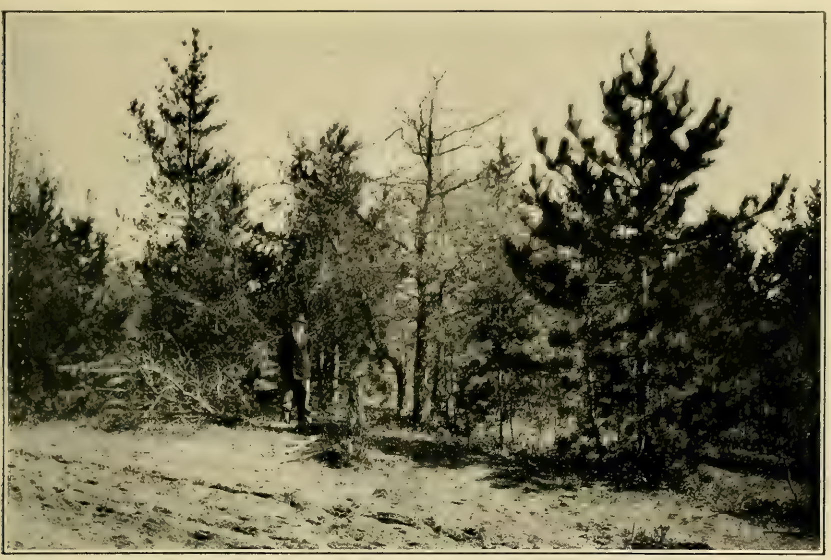

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FIG. 1.—TYPICAL OCCURRENCE OF JACK PINE IN MIXTURE WITH NORWAY AND WHITE PINE AND SCRUBBY SCARLET OAK ON EDGE OF PLAINS TYPE.

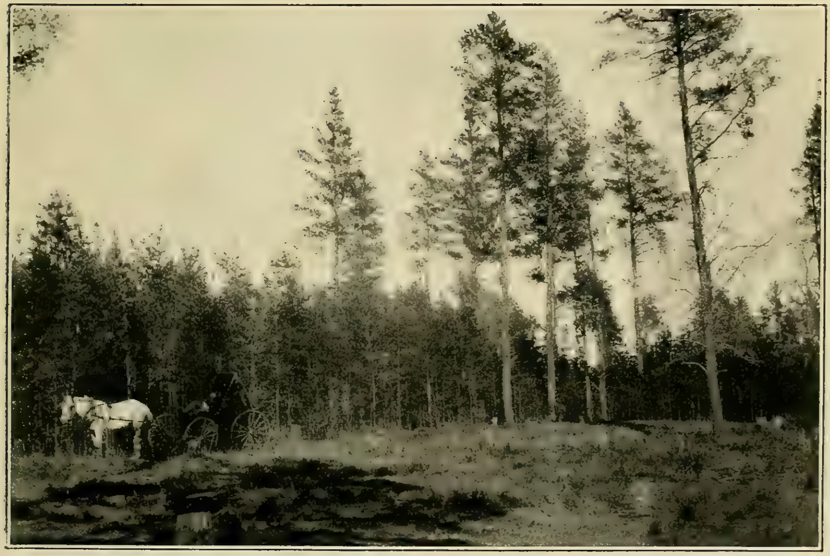

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FIG. 2.—YOUNG STAND OF JACK PINE AND THE OLD SEED TREES WHICH PRODUCED IT.

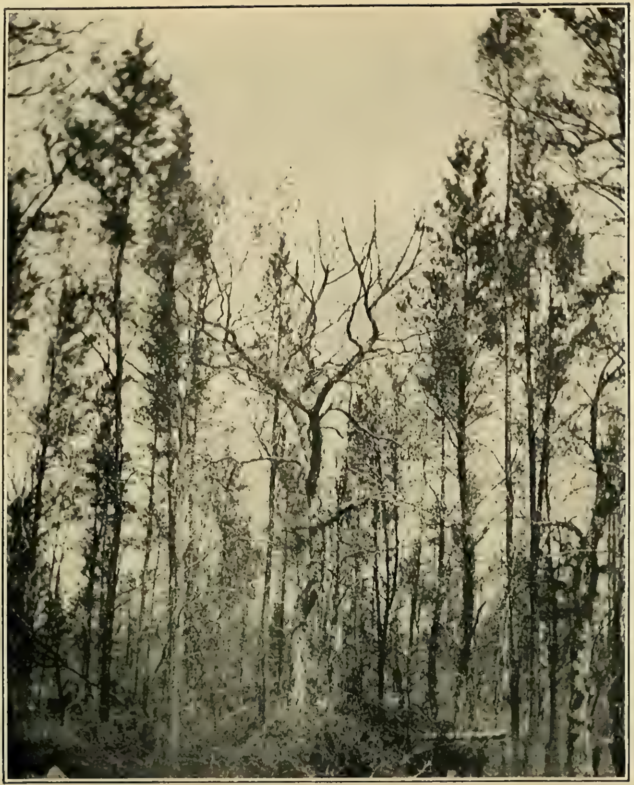

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Fig. 1.—Jack Pine, 35 Years Old, Overtopping Bur Oak, 100 Years Old, on Sandy, Jack Pine Soil, Adams County, Wis.

This is a common occurrence.

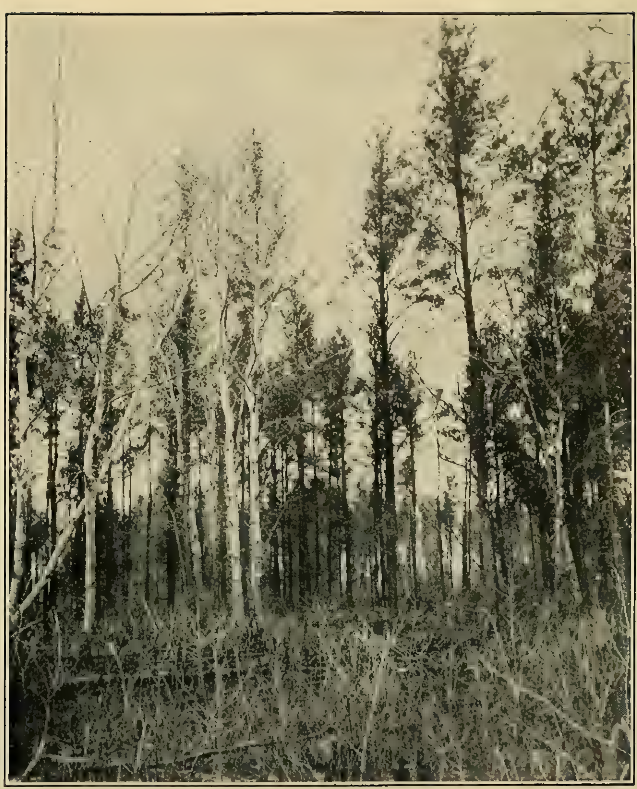

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Fig. 2.—Jack Pine, 40 Years Old and 56 Feet High, Slightly Overtopping Popple, of Same Age and 48 Feet High, on Sandy, Jack Pine Soil in Adams County, Wis.

The popple was more severely damaged by fire 12 years ago than was the jack pine.

and gravels), and collected in pockets. There are immense areas barren or valuable only for timber growing.

Jack pine is distinctly a tree of cold climates. Great variations of temperature take place within its range, and it occurs, for instance, where the winter temperature is often 60° F. below zero and the summer heat sometimes over 105° F. above. The growing season within its range varies from two to four months.

The heaviest rainfall of the jack-pine belt is in parts of Nova Scotia and New Brunswick, where it usually amounts to from 20 to 40 inches annually. The precipitation in the western portions of its range varies from 14 to 29 inches a year. Although essentially a dry-land tree, jack pine demands a climate with a moderate rainfall and produces the best stands where the annual precipitation is about 25 inches. Snowfall is generally abundant throughout its region of distribution, and protection is thereby afforded to the ground and the young growth.

FOREST TYPES.

Jack pine occurs chiefly in the following forest types: (1) In pure stands, on what is known as jack-pine land; (2) in mixture with Norway pine, on Norway pine land; (3) in mixture with white pine and other species, on white pine land; (4) in mixture with poplar (aspen); (5) in coniferous swamps and muskegs. The first and the last of these forest types occur throughout the range of the species, while the second and third are limited to the United States and the southern part of Canada. In general, the types in which jack pine occurs are relatively transient ones, as this species perpetuates itself in nature largely through the accidental agency of fire. (See Pls. III, IV, and V.)

JACK PINE LAND.

Land composed of poor, medium-to-coarse sands or land which is impoverished by fire and on which Norway or white pine does not readily spring up and thrive is the kind on which pure or nearly pure stands of jack pine constitute one of the principal forest types of the North. Even on this land, if for a number of years fires are excluded, soil and humus conditions improve and jack pine gradually gives way to the longer-lived and more persistent Norway pine, or in some cases to spruce. In the Lake States this land is usually known as "jack pine plain" because of its comparatively flat topography. In Canada it is usually known as "jack-pine ridge," although often it is only a few feet in elevation above the level of the coniferous swamp or muskeg. In the Lake States the "jack pine plain" in many cases formerly supported a good growth of Norway or white pine and the process of reversion to these species is now going on. On the border of the prairie region in Minnesota and Manitoba, "jack-pine prairies" occur which have only a scattering growth of small jack pine trees.

NORWAY PINE LAND.

Jack pine is found in mixture with Norway pine on fresh-to-dry flats and ridges of fine sand, jack pine sometimes composing one-half the stand.

WHITE PINE LAND.

On moist flats of very fine sand and silt, where white pine thrives, jack pine occurs sporadically as a subordinate tree. After lumbering and burning on these lands, however, jack pine may take possession and for a while form the dominant growth.

JACK PINE AND POPLAR (ASPEN).

Considerable areas bearing jack pine and poplar (aspen) are found in the western part of the range of jack pine in Canada. The type varies "from jack pine scattered in poplar to poplar scattered in jack pine. In these areas the jack pine is usually of very good growth, since it occupies better soils than it usually does."[1]

CONIFEROUS SWAMPS AND MUSKEGS.

In the Lake States jack pine grows only occasionally in swamps, but toward the north, as the number of tree species inhabiting muskegs gradually decreases, the proportion of jack pine in them becomes larger. However, in this type the jack pine is seldom of commercial importance.

Tables 29, 30, and 31 (appendix) show what species occur, more or less abundantly, with jack pine in the Lake States and in Canada on land where it is the prevailing tree. The appearance of tamarack and ash in Table 29 indicates that the edge of a swamp was included in some of the acres measured, as these species are not found in any of the jack-pine forest types.

SOIL, MOISTURE, AND LIGHT REQUIREMENTS.

Jack pine is primarily a tree of light, dry, medium to coarse, thoroughly drained sands and gravels. It is confined to geological formations which contain no limestone.[2] One of its important characteristics is its ability to reproduce and grow fairly well on thin, dry, sandy uplands where other species will not grow. Jack pine grows best, however, on fairly deep upland flats, where the drainage is good but the water table fairly near the surface. This is really Norway pine land, from which Norway pine usually crowds out the jack pine if fires are kept out.[3] (See Pls. V, VI, and VII.)

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[1] Extract from a letter by R. H. Campbell, Director of the Canadian Forestry Branch.

[2] See B. Moore in Vol. XVII, p. 887, of the Journal of Forestry.

[3] Table 17 (appendix) indicates that in northern Minnesota jack pine stands occur prevailingly on medium to coarse sands, Norway pine stands on fine sand, and white pine stands on very fine sands and silts. (Medium to coarse sands comprise in a large degree the "Soils of the Laurentian country in Canada, where jack pine reaches its best development." See Forestry Quarterly, Vol. IX, No. 1, p, 7.)

Most of the soil on which jack pine occurs has little or no accumulation of humus. Accumulation of humus would mean, in some cases, improved soil conditions and the ousting of jack pine by more persistent, longer-lived species.

Jack pine requires at least 10 per cent of water in the soil for its best growth. On very dry soils young stands of jack pine may do well at the outset, but the growth is not sustained, the trees do not reach large size, and the stand becomes more open because of competition for soil moisture. To a limited extent jack pine grows in swamps also, but in a stunted form.

Jack pine is intolerant of shade, somewhat more so than Norway, and considerably more so than white pine. For this reason it is unable to reproduce itself under the shade of mature trees. Jack pine stands which are dense up to the age of from 30 to 50 years thin out rapidly thereafter even on good sites. On lands suited to white or Norway pine, but which become seeded up to dense stands of jack pine following lumbering and fire, these species, through their superior tolerance and persistence in growth, gradually seed in and push themselves up through the jack pine and kill it out entirely, not, however, before the jack pine has reached merchantable size.

FORM AND DEVELOPMENT.

In dense stands jack pine is a tall, slender tree, with a short crown and a long bole. In open stands it tends to develop a dome-shaped, wide-spreading crown and a short bole. The dead branches are very persistent, normally remaining on the trunk from the live crown almost to the ground during most of the life of the tree.

The size of a mature jack pine tree varies greatly in different portions of its range. In northern and western Minnesota, where jack pine forests attain their best development in the United States, dominant forest-grown trees which reach maturity when from 80 to 100 years old are usually from 60 to 80 feet tall and from 10 to 15 inches in diameter at breast height. Older trees are frequently found which are 85 feet high and 15 or 16 inches in diameter. Trees 90 feet in height and over 20 inches in diameter are sometimes found, but these are the exception, and indicate better soil conditions than usually obtain where jack pine grows. After reaching 80 years of age, and sometimes sooner, jack pine deteriorates rapidly.

On the jack pine plains in the northern half of the Southern Peninsula of Michigan there are many miles of pure young jack pine forest in which there are few, if any, trees over 75 feet in height or more than 14 inches in diameter. Frequent fires have thinned many of these stands and as a result large numbers of the trees are scrubby and branchy. On the Michigan National Forest in the Lower Peninsula jack pine averages from 4 to 6 inches in diameter and from 30 to 40 feet in height, and only infrequently is it found over 8 or 9 inches in diameter and 50 feet in height. The small diameter of the trees is explained by the fact that most of the stands are comparatively young. In the Upper Peninsula of Michigan jack pine stands occur on better soils and are favored with a heavier rainfall than are those found in the lower peninsula. Therefore the average size of the trees is larger and the quality is better. Trees have been found here 18 inches and over in diameter, 90 feet in height, and 150 years of age. (See Pl. VIII.) Most of the stands are, however, composed of young and small trees.

On the eastern outskirts of its range in New England where a few jack pine groves occur, the height of the trees is usually only from 15 to 20 feet. These groves are composed of comparatively young trees. In Nova Scotia and eastern Canada also this species is of small size.

In the region north and west of Lake Superior and west of Lake Winnipeg jack pine reaches its best development. Here it is occasionally 90 feet in height and 20 inches in diameter. North of Lake Winnipeg it seldom exceeds 8 inches in diameter and 50 feet in height.[1]

Tables 18 to 28 (appendix) indicate the form and growth of jack pine trees in regard to width of crown, thickness of bark, taper, and volume expressed in different units of measure.

ROOT SYSTEM.

On deep, sandy soil where the water table is low, jack pine produces a long characteristic taproot. On loose soil the lateral roots spread outward only a short distance and then descend parallel to the taproot. During the first year seedlings on this quality of soil send a taproot down from 6 to 12 inches, and develop very few laterals. (See fig. 2.) On better soils a widely branched, surface-feeding root system is developed early because of the relatively large amount of food and moisture near the surface. At the same time a more or less pronounced taproot is sent down, though this does not develop as rapidly as on sandy soil. On shallow and wet soils jack pine develops only lateral roots.

RATE OF GROWTH.

Tables 1 to 8, inclusive, indicate the rate of increase in diameter and height of single trees of jack pine growing in different regions and under different conditions.

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[1] See Forestry Quarterly, December, 1916.

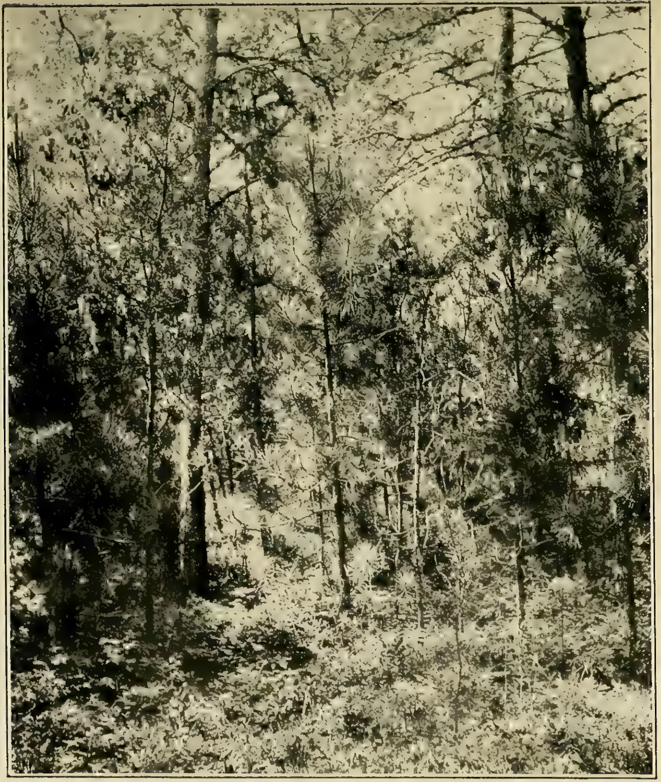

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FIG. I.—NORWAY PINE REPRODUCTION COMING IN UNDER A THICK STAND OF JACK PINE IN WHICH THERE HAS BEEN NO FIRE FOR A NUMBER OF YEARS.

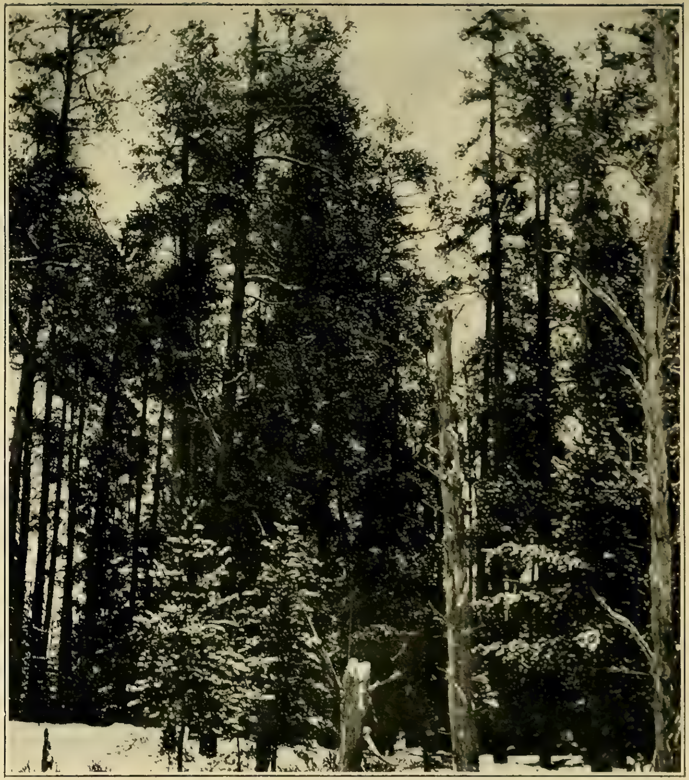

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FIG. 2.—STAND OF JACK PINE 150 YEARS OLD ON SANDY RIDGE BETWEEN SPRUCE-TAMARACK SWAMPS.

There has been no fire here for some time and a spruce understory has sprung up in places.

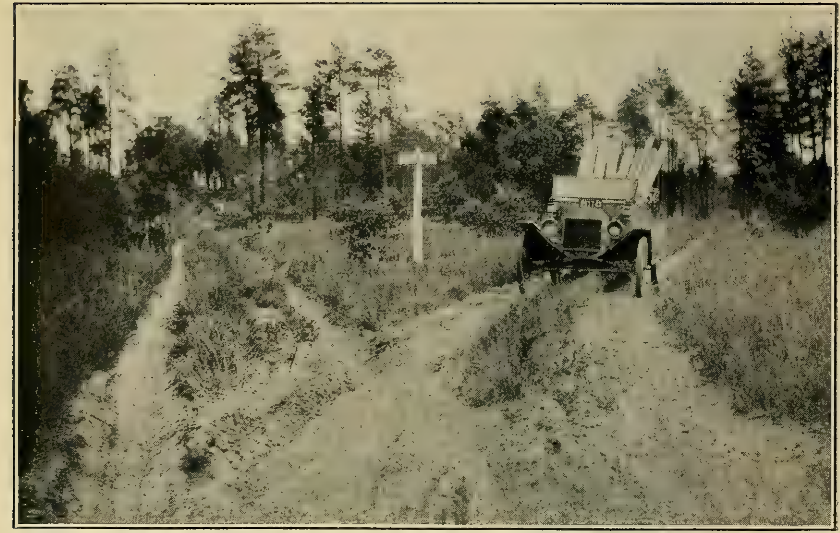

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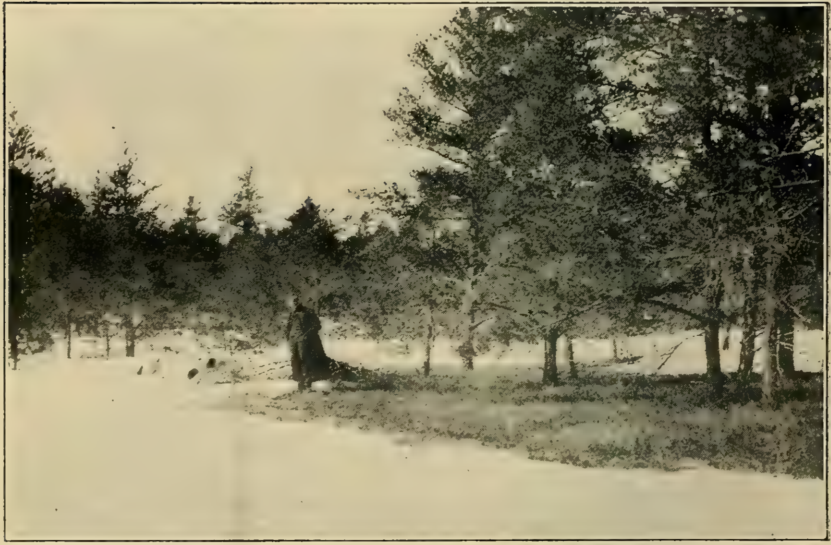
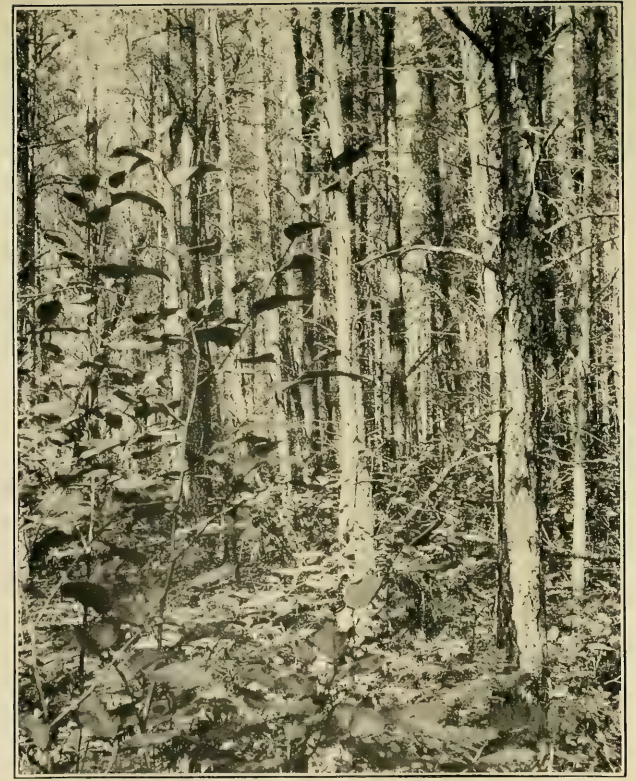
FIG. 1.—TYPICAL JACK PINE PLAIN OF VERY SANDY SOIL.



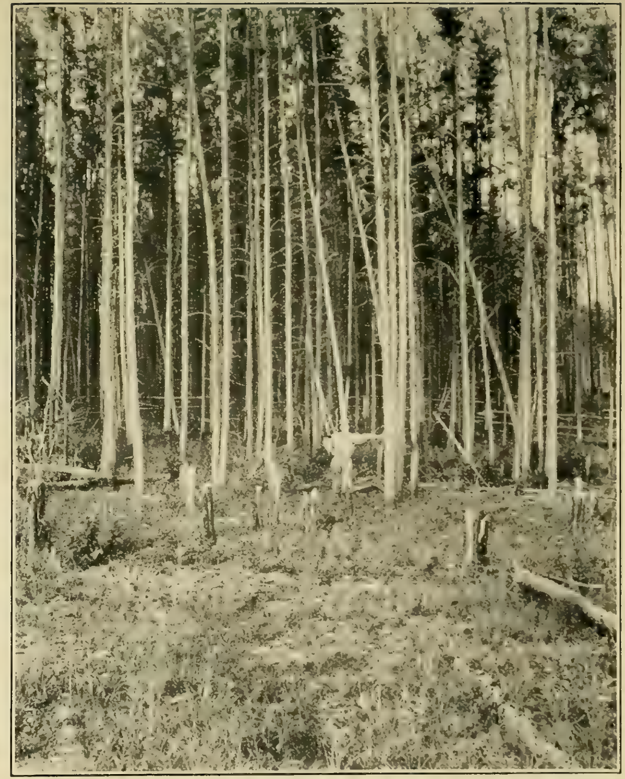
F-75101

FIG. 2.—TYPICAL GROWTH OF JACK PINE ON JACK PINE PLAINS IN MICHIGAN. STAND DENSE IN SPOTS AND OPEN IN OTHERS.



F-64793

FIG. I.—FORTY-FIVE-YEAR-OLD STAND ON CLAY SOIL, SHOWING UNDERBRUSH WHICH IS TYPICAL OF GOOD SOILS WHERE THERE HAS BEEN NO FIRE.

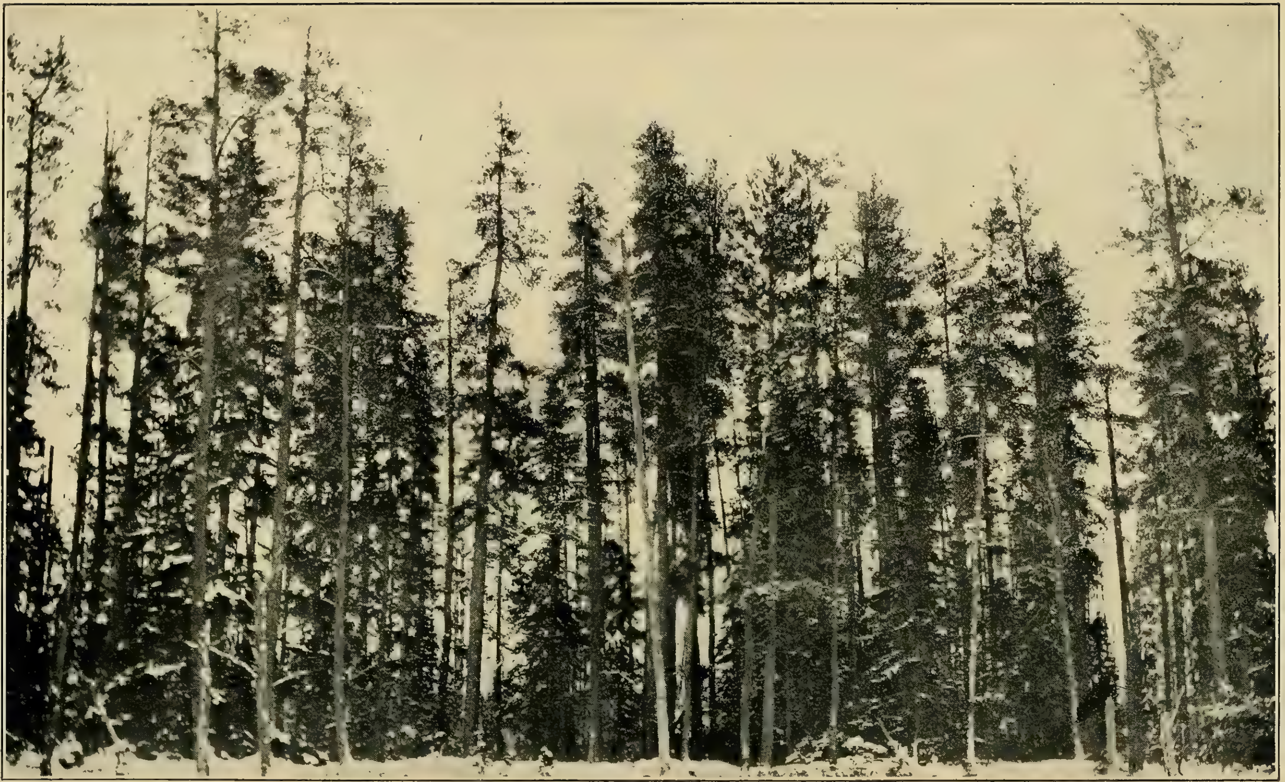


F-64786

FIG. 2.—FIFTY-FIVE-YEAR-OLD STAND ON PURE SAND, SHOWING WELL-CLEANED BOLES.

Note lack of undergrowth on sandy site. Also trees thinning out and growth at a standstill.

DENSE STANDS OF JACK PINE ON CLAYEY AND SANDY SOILS. HUBBARD COUNTY, MINN.



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STAND 150 YEARS OLD AND TREES 10 TO 18 INCHES IN DIAMETER, 70 TO 90 FEET HIGH, AND 30 TO 50 FEET CLEAR LENGTH, ON LOW SANDY RIDGE BETWEEN SPRUCE-TAMARACK SWAMPS.

A very exceptional stand of jack pine in regard to size and age and quality of the timber. Overmaturity is indicated by the unhealthy appearance of the crowns.

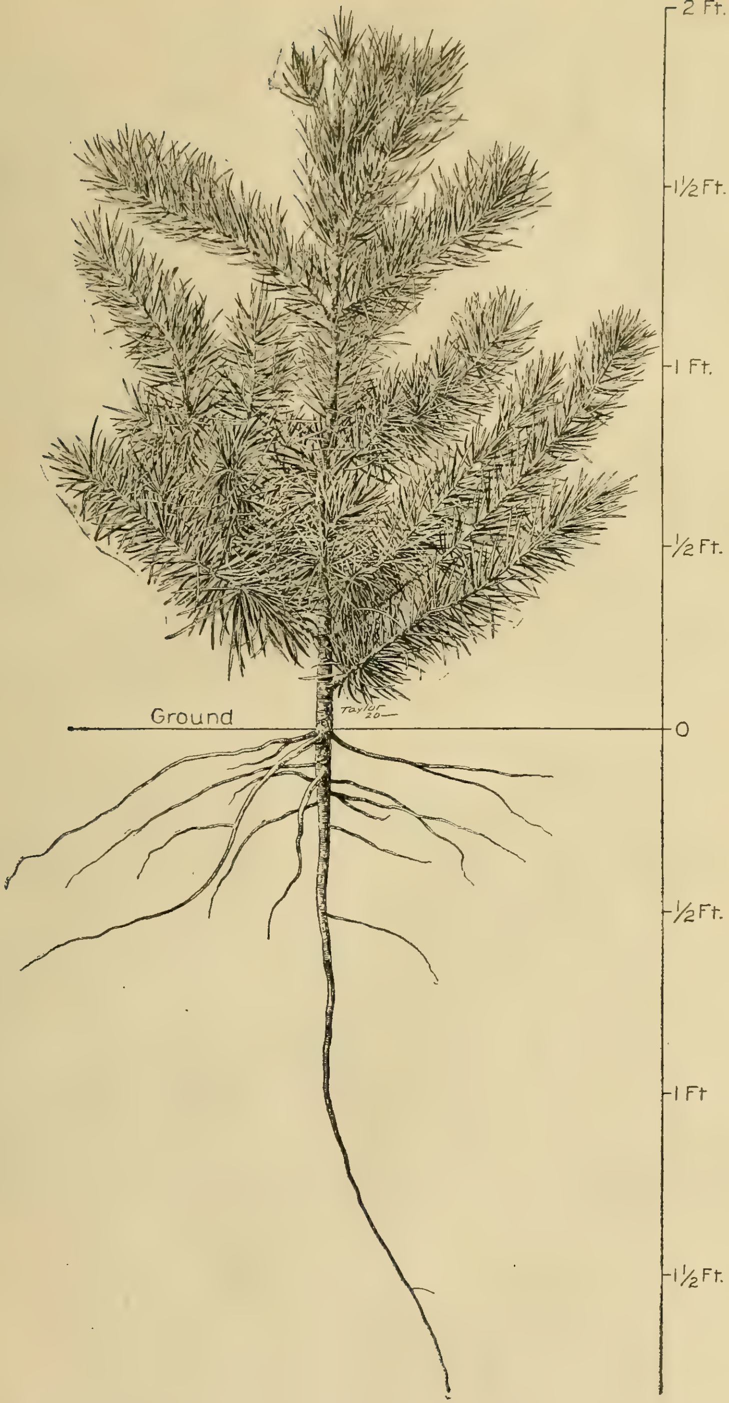
2 Ft.
1½ Ft.
1 Ft.
½ Ft.
Ground
Taylor 20
0
½ Ft.
1 Ft
1½ Ft.

FIG. 2.—Three-year-old jack pine 2 feet high showing well-developed root system with long tap root.

TABLE 1.—*Rate of growth in diameter and height of jack pine, in dense stands and of isolated or nearly isolated trees, in Hubbard County, Minn.*

Age.	Trees in dense stands 18 to 99 years old.				Isolated or nearly isolated trees 22 to 82 years old.	
	Average.		Maximum.		Average growth.	
	D. b. h.	Height.	D. b. h.	Height.	D. b. h.	Height.
Years.	*Inches.*	*Feet.*	*Inches.*	*Feet.*	*Inches.*	*Feet.*
10	1.2	9	1.8	19	1.7	12
15	2.3	16	3.8	26	3.5	22
20	3.3	22	5.5	33	5.1	29
25	4.0	28	6.9	38	6.6	35
30	4.6	33	7.9	42	7.9	39
35	5.1	38	8.8	46	9.1	42
40	5.6	42	9.5	50	10.2	44
45	6.1	45	10.2	53	11.1	46
50	6.5	48	10.9	56	11.8	47
55	6.9	51	11.5	59	12.5	47
60	7.3	54	12.1	62	13.1	48
65	7.6	57	12.7	65	13.7	49
70	8.0	59	13.3	68	14.2	49
75	8.3	62	13.9	70	14.8	50
80	8.7	64	14.5	72	15.3	50

Based on 604 trees, 18 to 99 years old. Measurements by H. H. Chapman.

Table 1 indicates a much faster diameter growth of isolated and partly isolated trees than the average growth of trees in dense stands—faster even than the average growth of predominant trees in such stands.

TABLE 2.—*Rate of growth in diameter and height of jack pine in Cass County, Minn.*

Age.	Average.		Maximum.		Age.	Average.		Maximum.	
	Diameter breast high.	Height.	Diameter breast high.	Height.		Diameter breast high.	Height.	Diameter breast high.	Height.
Years.	*Inches.*	*Feet.*	*Inches.*	*Feet.*	*Years.*	*Inches.*	*Feet.*	*Inches.*	*Feet.*
5	....	3	....	12	65	8.4	63	11.1	72
10	0.6	10	1.4	20	70	8.8	65	11.6	74
15	1.5	16	2.8	28	75	9.2	68	12.1	76
20	2.4	23	4.1	35	80	9.6	70	12.6	78
25	3.3	30	5.3	41	85	10.0	71	13.0	80
30	4.2	35	6.3	47	90	10.4	73	13.4	82
35	5.0	40	7.2	52	95	10.8	74	13.8	83
40	5.7	45	8.1	57	100	11.2	75	14.2	85
45	6.3	50	8.8	61	105	11.6	76	14.6	86
50	6.9	53	9.5	64	110	11.9	77	15.1	88
55	7.4	57	10.1	67	115	12.3	78	15.5	89
60	7.9	60	10.6	70	120	12.6	79	15.9	90

Based on 52 trees 69 to 124, averaging 93 years old, and 7 to 16 inches in diameter, the trees having been cut for saw logs. Measurements by J. St. J. Benedict.

TABLE 3.—*Rate of growth in diameter of second-growth jack pine in northern Minnesota.*

Age.	Diameter breast high.		Age.	Diameter breast high.	
	Maximum.	Average.		Maximum.	Average.
Years.	*Inches.*	*Inches.*	*Years.*	*Inches.*	*Inches.*
5			30	7.7	5.7
10	1.8	1.2	35	8.6	6.5
15	3.6	2.5	40	9.5	7.3
20	5.2	3.8	45	10.3	8.1
25	6.5	4.8	50	11.1	8.9

NOTE.—Based on decade measurements on 46 1-foot stumps 32 to 51 years old. Measurements by J. St. J. Benedict, in Cass County, Minn.

TABLE 4.—*Rate of growth in diameter and height of dominant jack pine trees in Crawford and Roscommon Counties, Mich.*

Age.	Average dominant growth.		Maximum growth.		Age.	Average dominant growth.		Maximum growth.	
	Diameter breast high.	Total height.	Diameter breast high.	Total height.		Diameter breast high.	Total height.	Diameter breast high.	Total height.
Years.	*Inches.*	*Feet.*	*Inches.*	*Feet.*	*Years.*	*Inches.*	*Feet.*	*Inches.*	*Feet.*
5		2		4	55	8.4	55	11.0	67
10	0.8	8	1.5	13	60	8.8	58	11.5	70
15	2.0	15	3.2	22	65	9.2	61	12.0	72
20	3.1	22	4.8	31	70	9.6	63	12.4	74
25	4.2	28	6.3	39	75	10.0	64	12.8	75
30	5.2	34	7.5	45	80	10.3	65	13.1	76
35	6.0	39	8.4	51	85	10.7	66	13.5	77
40	6.7	44	9.3	56	90	11.1	67	13.9	78
45	7.3	48	9.9	61	95	11.5	67	14.3	79
50	7.9	52	10.5	64	100	11.8	68	14.7	80

Diameters based on decade measurements on 122 1-foot stumps 25 to 104 years old. It was assumed that it would take 4 years to grow to a stump height of 1 foot.

Heights based on sectional age counts on 150 trees 25 to 104 years old.

Measurements by T. H. Sherrard, 1901.

TABLE 5.—*Measurements*[1] *on 13 trees in a dense young stand of jack pine on sandy pine plain in the Upper Peninsula of Michigan.*

[The trees were cut for pulpwood in 4-foot lengths and taken to a top diameter of 4 inches, with an average of 122 pieces per cord. See Pl. XII.]

	Average.	Maximum.	Minimum.
Age ... years	47	55	40
Height ... feet	50.8	57	44
Diameter, breast high ... inches	6.9	9	5.5
Volume in board feet (possible mill cut of round-edge material)	28	60	15
Clear length ... feet	0	0	0
Merchantable length ... feet	31.6	44	24
Number of 4-foot sticks per tree	8	11	6

[1] Measurements by Huber C. Hilton, 1918.

TABLE 6.—*Measurements*[1] *on 22 trees in a fairly dense, somewhat mature to overmature stand of jack pine in the Upper Peninsula of Michigan.*

[The trees were cut for saw logs. Stand located on a low sandy ridge, slightly elevated above a muskeg swamp on one side, and above a lower area of spruce, tamarack, and some jack pine on the other. Soil, coarse sand underlaid with clay subsoil. See Pl. VIII.]

	Average.	Maximum.	Minimum.
Age..........years..	104	125	68
Height..........feet..	72.5	88	61
Diameter, breast high..........inches..	12.2	17	9.8
Volume in board feet, Scribner decimal rule..........	128	290	50
Volume in board feet (mill scale of possible round-edge)..........	175	430	90
Clear length..........feet..	34	50	0
Merchantable length..........do....	46.4	60	32
Number of 16-foot logs..........	3	3¾	2

[1] Measurements by Huber C. Hilton, 1918.

TABLE 7.—*Rate of growth, in diameter and height, of jack pine, on good sites in western Ontario.*[1]

Age	Diameter breast high.	Height.	Age.	Diameter breast high.	Height.
Years.	*Inches.*	*Feet.*	*Years.*	*Inches.*	*Feet.*
5..........	----	1.5	60..........	11.7	64
10..........	0.8	8	65..........	12.4	67
15..........	2.0	17	70..........	13.0	70
20..........	4.0	28	75..........	13.5	72
25..........	5.8	36	80..........	14.0	74
30..........	7.1	42	85..........	14.5	76
35..........	8.1	46	90..........	14.9	77
40..........	8.9	50	95..........	15.2	79
45..........	9.6	54	100..........	15.6	80
50..........	10.3	58	105..........	15.9	81
55..........	11.0	61	110..........	16.2	81.5

[1] From an article by L. M. Ellis, in the Forestry Quarterly, for Mar. 1, 1911.

Based on 100 trees.

TABLE 8.—*Average rate of growth, in diameter, of 50 representative jack pine trees, on the Riding Mountain Reserve, Manitoba, Canada.*[1]

Age.	Diameter breasthigh (outside bark).	Age.	Diameter breasthigh (outside bark).
Years.	*Inches.*	*Years.*	*Inches.*
10..........	0.5	60..........	10.1
20..........	2.8	70..........	11.0
30..........	5.4	80..........	11.7
40..........	7.3	90..........	12.2
50..........	8.8	100..........	12.6

[1] From Bulletin 6, "Wood-Using Industries of the Prairie Provinces," of Canadian Forestry Branch. This bulletin states that: "Jack pine in closed stands on the Riding Mountain Reserve reaches 60 to 80 feet in height by 12 to 18 inches in diameter, with straight, clear trunks yielding a good grade of saw and tie timber. But where open grown they are a mass of limbs right to the ground, and of little value, even for firewood.

Table 3, relating to trees grown in Cass County, Minn., shows a less rapid diameter growth than Table 2, which refers to other trees grown in the same county, probably because those covered in Table 3 are comparatively open grown, thrifty second growth.

Table 4 indicates the average dominant and the predominant growth on jack-pine land of good quality in the northern part of the Southern Peninsula of Michigan.

Tables 5 and 6 indicate the development of jack pine in dense stands on good sites in the southern part of the Upper Peninsula of Michigan.

Table 7 indicates the rate of growth on good sites in western Ontario, a region very favorable to the growth of jack pine.

Table 8 shows the growth on poorer soil in Manitoba.

Tables 9 and 10, which are not comparable with Table 1, being based on different data, show the average growth and yield at different ages of dense, even-aged, unmanaged stands of jack pine on sandy soils in Hubbard County, Minn. These stands have been more or less damaged at one time or another by ground fires which were not sufficiently severe to kill many trees, but which without doubt appreciably lessened the vitality and rate of growth of a large number of them.

TABLE 9.—*Rate of growth and yield per acre of pure, even-aged, densely stocked stands of jack pine in Hubbard County, Minn.*

SITE QUALITY "GOOD."

Age.	Trees per acre.			Average.			
				Basal area.	D. b. h.	Dominant height.	Yield per acre.[1]
	Total.	5 inches and over.	10 inches and over.	5 inches and over.	5 inches and over.		
Years.	*Number.*	*Number.*	*Number.*	*Sq. ft.*	*Inches.*	*Feet.*	*Cu. ft.*
20	1,120	94		15	5.4	30	730
25	839	153		28	5.8	37	1,090
30	672	281		57	6.1	43	1,630
35	565	391	7	90	6.5	48	2,480
40	485	404	26	102	6.8	52	2,970
45	432	393	39	108	7.1	56	3,260
50	398	382	45	111	7.3	60	3,470
55	374	371	48	114	7.5	63	3,660
60	358	358	51	115	7.7	66	3,840
65	345	345	53	116	7.8	69	4,010
70	332	332	53	116	8.0	71	4,180
SITE QUALITY "POOR."							
25	1,400	71		10	5.1	29	660
30	1,091	138		22	5.4	35	930
35	846	203		36	5.7	40	1,250
40	698	279		53	5.9	44	1,590
45	602	330		67	6.1	48	1,900
50	537	360		78	6.3	51	2,180
55	490	373	6	86	6.5	54	2,430
60	450	376	17	92	6.7	56	2,660
65	412	374	25	97	6.9	58	2,870
70	377	364	30	100	7.1	60	3,080

[1] Total volume, including bark, of all trees 2 inches and over in diameter, breast high.

Based on 128 plots; area, 90.2 acres. Measurements by H. H. Chapman.

TABLE 10.— *Yield per acre of pure, even-aged, densely stocked stands of jack pine in Hubbard County, Minn., calculated in cubic feet, cords, and board feet.*

SITE QUALITY "GOOD."

Age.	Yield per acre.						
	Trees 5 inches and over.	Trees 5 inches and over.		Mill tally.[4]		Scribner Decimal C.[5]	
		With bark.[2]	Peeled.[3]	Trees 5 inches and over.	Trees 8 inches and over.	Trees 8 inches and over.	Trees 10 inches and over.
Years.	*Cu. ft.*[1]	*Cords.*	*Cords.*	*Board ft.*	*Board ft.*	*Board ft.*	*Board ft.*
20	160	1.6	1.3	500	....	....	....
25	650	6.5	5.3	3,200	700	300	....
30	1,360	13.6	11.2	6,900	1,900	700	....
35	2,210	22.1	18.2	10,500	3,200	1,400	300
40	2,800	28.0	23.1	13,200	4,700	2,300	1,300
45	3,160	31.6	26.1	14,900	6,500	3,800	2,200
50	3,420	34.2	28.3	16,300	8,600	5,200	2,900
55	3,640	36.4	30.1	17,400	10,700	6,200	3,400
60	3,840	38.4	31.8	18,500	12,500	6,900	4,000
65	4,010	40.1	33.3	19,600	14,000	7,600	4,400
70	4,180	41.8	34.7	20,600	15,300	8,200	4,800
SITE QUALITY "POOR."							
25	130	1.3	1.1	700	....	....	....
30	470	4.7	3.8	2,200	....	....	....
35	870	8.7	7.1	4,000	....	....	....
40	1,300	13.0	10.6	6,200	200	....	....
45	1,670	16.7	13.7	8,100	1,100	400	....
50	1,990	19.9	16.3	9,600	2,200	800	....
55	2,280	22.8	18.7	10,900	3,400	1,500	300
60	2,550	25.5	21.0	12,200	4,900	2,500	1,000
65	2,790	27.9	23.0	13,400	6,600	3,800	1,600
70	3,010	30.1	24.9	14,500	8,200	4,900	2,100

[1] Total volume of stem, including bark.
[2] 100 cubic feet equal 1 cord.
[3] Per cent of bark in total volume, 18.9 down to 16.9, decreasing with increase in age.
[4] Scaled by white-pine mill-cut table. See Table 27, in appendix.
[5] Stump height, 1 foot; diameter inside bark at top, 5.5 inches, scaled by Table 25 (appendix).

Based on plots given in Tables 34 and 35 in the appendix.

In these tables "good" quality of site indicates the better classes of soils which would be suitable for growing Norway pine, while "poor" quality indicates those soils not so well adapted to Norway pine.

Tables 34 and 35 (appendix) give the details of the field measurements of the plots used as the basis of Tables 9 and 10. All of these plots were used as a basis for determining the total cubic volume. The items other than total cubic volume were based on selected plots classified as qualities "good" and "poor" on the basis of their total cubic yield. This classification corresponds closely to a classification based on the average dominant heights of the different plots. (See fig. 3, facing p. 16.) The plots selected were those whose total cubic volumes were close to the average curves for total cubic volumes.

Table 11 shows the growth and yield of six plots at different points in northern Minnesota, the data having been collected and computed by State Forester Cox. Under the heading, "Quality of site," these plots are compared as to cubic-foot yield with those in Hubbard County (Table 9), and the site quality averages "poor." One plot at Cloquet, Minn., ranks somewhat higher than that given under site quality "good" in the Hubbard County yield table.

TABLE 11.—*Yield per acre of six sample plots in dense, even-aged stands of jack pine on sandy soil in northern Minnesota.*[1]

	Plot 1, Cloquet, age 13 years.	Plot 2, Cloquet, age 37 years.	Plot 3, Park Rapids, age 39 years.	Plot 4, Ferris, age 40 years.	Plot 5, Bemidji, age 62 years.	Plot 6, Cass Lake, age 66 years.
Total number of trees	10,464	586	800	460	180	252
Average diameter breast high, inches	1.5	6.5	5.4	5	10	9
Average total height......feet..	16	48.5	44	48.5	67	70.5
Yield per acre......cubic feet..	282.53	3,142.68	1,989	984.4	2,481	3,102
Yield per acre..........cords..	3.95	44	27.8	13.78	34.7	43.43
Yield per acre......board feet..	1,978	21,999	13,925	6,891	17,367	21,715
Quality of site	[2] Poor.	[2] Good.	[2] Poor.	[2] Very poor.	[2] Poor.	[2] Poor.
Average annual increment, cubic feet	21.6	85	51	24.6	40	47
Average annual increment, cords	3	1.19	0.7	0.34	0.56	0.66
Average annual increment, board feet	152	593	357	172	280	330

[1] From data collected and computed by the Minnesota Forest Service in 1913.
[2] Compared with cubic-foot yields in Hubbard County, Minn. See Table 9.

Table 12 shows the growth and yield of 12 plots in typical stands in Adams County, Wis., on sandy soils covered with pure stands of jack pine. Under the heading, "Quality of site," these plots are compared as to cubic-foot yield with those in the Hubbard County yield table (Table 9), and the site quality easily averages "good," some of the plots ranking much higher than the site designated as "good" in Table 9.

TABLE 12.—*Stand and yield per acre of 12 sample plots in dense, even-aged stands of jack pine on sandy soil in Adams County, Wis.*

Age of plot.	Living trees per acre.						Average.		Basal area.		Total yield per acre.	Quality of site.[1]
	Total.	Jack pine.		Other species.			Diameter, breast high (5 inches and over).	Dominant height.	1 inch and over.	5 inches and over.		
		5 to 9 inches.	10 inches and over.	1 to 4 inches.	5 to 9 inches.	10 inches and over.						
Years.								*Feet.*	*Sq. ft.*	*Sq. ft.*	*Cu. ft.*	
23	530	280	......	......	......	......	5.6	32	62	48	949	Good.
25	950	460	......	10	......	......	5.9	42	114	88	2,337	Very good +.
31	390	250	30	110	20	......	7.6	45	96	87	1,995	Good +.
32	400	300	60	200	......	......	8.0	46	127	125	2,971	Very good.
32	490	370	40	70	......	......	7.5	48	131	127	3,085	Do.
34	416	344	8	184	24	......	7.5	49	113	109	2,550	Good +.
36	410	310	20	60	50	......	7.3	50	101	96	2,465	Good −.
40	336	272	56	24	......	......	7.9	50	113	113	2,572	Good −.
41	408	304	32	16	24	......	7.5	53	110	104	2,686	Good −.
50	560	260	......	240	30	......	6.4	38	73	59	1,352	Very poor.
50	330	200	80	130	40	......	8.8	50	120	118	2,834	Poor +.
50	300	190	90	30	40	......	8.6	60	114	113	3,310	Good −.

[1] Compared with cubic-foot yields in Hubbard County, Minn. See Table 9.

Measurements by the author, 1917.

It is interesting to compare the growth and yield of unmanaged natural jack pine stands as shown in Tables 9 and 10, with the growth and yield of well-managed Scotch pine stands in Europe, as shown in Table 32 (appendix). In yield per acre the "good" quality site in the Hubbard County table averages between site qualities II and III for Scotch pine, and the "poor" quality site averages between IV and V. In the matter of height, the Hubbard County trees on sites whose quality is described as "good" and "poor" rank considerably higher than the Scotch pine trees on the above-mentioned sites. This may be partly accounted for by the fact that Table 9 gives the average dominant height, while Table 32 gives the average height of the stand. In general, however, a comparison of the greater heights and lesser yields of unmanaged jack pine stands with the lesser heights and greater yields of managed Scotch pine suggests the possibility of increasing the yield of jack pine by growing it under management.

Table 13 gives the average annual increment in cubic feet and board feet of the stands of different ages computed on the basis of volumes given in Tables 9 and 10.

TABLE 13.—*Mean annual increment of pure, even-aged, densely stocked stands of jack pine, figured in total cubic feet for trees 5 inches and over in diameter, in board feet mill scale for trees 5 inches and over and for trees 8 inches and over in diameter, and in board feet by Scribner log rule for trees 8 inches and over in diameter.*

Age.	Site quality good.					Site quality poor.				
	Total.	Mill scale.			Scribner.	Total.	Mill scale.			Scribner.
		5 inches and over.	5 inches and over.	8 inches and over.	8 inches and over.		5 inches and over.	5 inches and over.	8 inches and over.	8 inches and over.
Years.	*Cu. ft.*	*Cu. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Cu. ft.*	*Cu. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
20	36	8	25	....	....	....	....	....	....	....
25	44	26	128	28	12	26	5	28	....	....
30	54	45	230	73	23	31	16	63	....	....
35	71	63	300	114	40	36	25	91	....	....
40	74	70	330	155	58	40	32	118	5	....
45	72	70	331	180	84	42	37	144	24	9
50	69	68	326	192	104	44	40	172	44	16
55	67	66	316	198	113	44	41	195	62	27
60	64	64	308	203	115	44	42	208	82	42
65	62	62	302	206	117	44	43	215	102	58
70	60	60	294	207	117	44	43	219	117	70

STANDARD SITES.

In figure 3 are exhibited all the available age-height data plotted in accordance with Prof. Roth's plan for site classification.[1] According to this plan all species whose dominant trees reach an average height of only 90 feet in 100 years on the best sites (to be called Site I for those species) are to be classified as standard C species, stand-

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[1] See Forestry Quarterly, March, 1916.

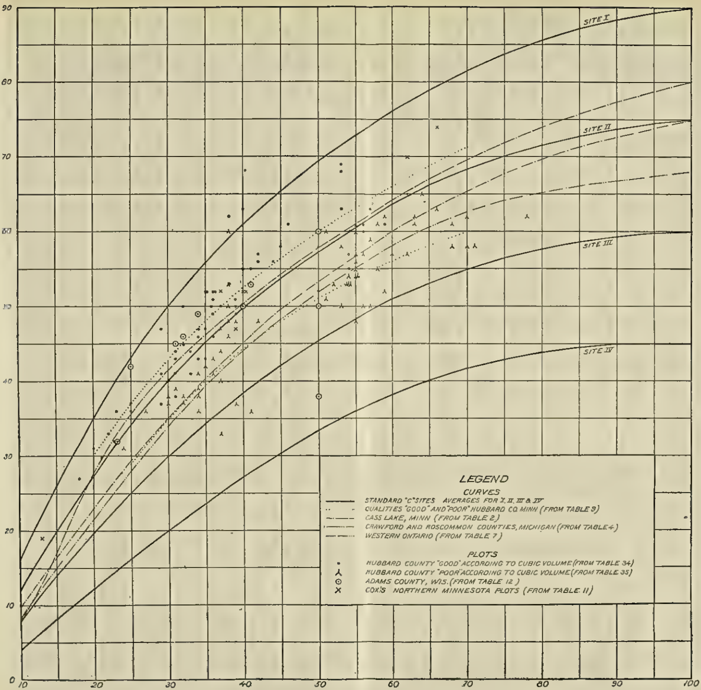

FIG. 3.—Jack pine age-height data and curves plotted with reference to Prof. Roth's plan for site classification standard C. Shows average height of dominant trees in stands of different ages.

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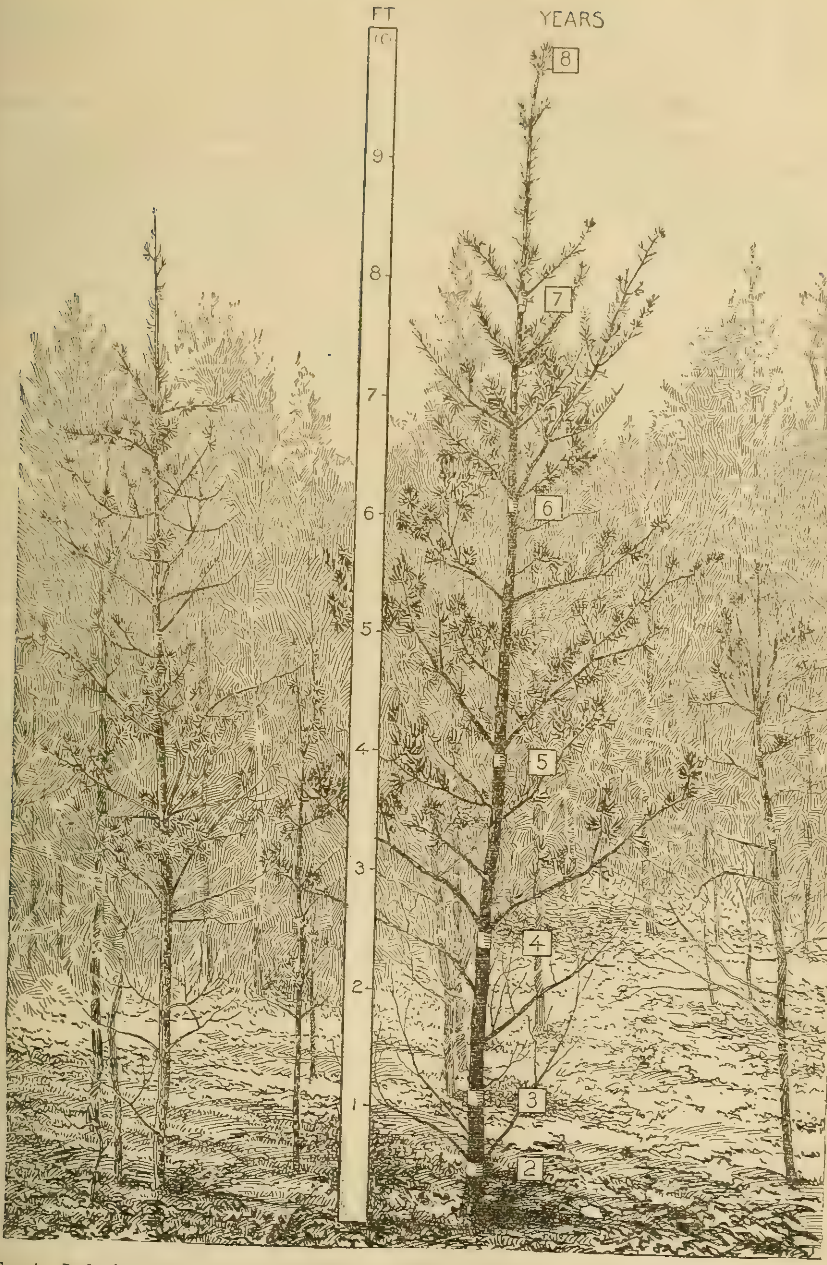

FIG. 4.—Jack pine saplings 8 years old and 10 feet high. Paper tied around nodes indicates termination of esch successive year's growth, and shows several whorls of lateral branches (usually 3) for each year, which is characteristic of this species.

ards A and B being for higher-growing species. In a letter reviewing the manuscript on which this bulletin is based Prof. Filibert Roth says:

> I recommend that this standard of 90, 75, 60, and 45 feet for I, II, III, and IV sites be made a regularly accepted or adopted standard and called standard C, and that all species in the United States which have a growth near to jack pine have their sites established and measured by this same standard C site classification on the basis of height at 100 years, with values as given in figure 3, which works out well with data here gathered.
>
> Site I in older stands is represented sparingly in these studies (referring to the manuscript), because in Minnesota jack pine does not get a chance on Site I, since these run to Norway pine.
>
> Site IV is also little represented, but is abundant in Wisconsin and Michigan.

It will be seen that the "good" site in Hubbard County is slightly better than Roth's Site II, while the "poor" site is halfway between Sites II and III.

REPRODUCTION.

SEED PRODUCTION.

Jack pine produces a great quantity of seed. In view of the comparative shortness of the life of jack pine and its intolerance of shade, this characteristic is extremely important. As a matter of fact, the fruitfulness of jack pine, combined with its ability to grow on soils too poor, at the outset, for other species, is the means by which it is able to maintain itself as one of the most widespread and important forest types of the North. (See Pls. IX and X.) Jack pine, like lodgepole, is a "fire tree," quickly seeding up bare-burned spots or areas. It seeds well almost every year and heavily every two or three years, in contrast with Norway and white pines, which do not seed every year and which seed in abundance only at intervals of from five to seven years and three to five years, respectively. Trees in the open or with abundant growing space are the most prolific seeders and commence to bear seed when from 6 to 8 years old. Vigorous seed production continues up to 80 years of age, but is most vigorous between 40 and 80 years.

A well-developed, vigorous tree produces from 1,000 to 1,200 cones in a year, or from one-fourth to one-half bushel, and these cones contain from one-fourth to one-half pound of seed, each cone having from 25 to 50 seeds.[1] Very heavily loaded jack pines sometimes yield 1½ bushels of cones. There are from 75,000 to 100,000 seed per bushel of cones, and from 100,000 to 150,000 seed per pound. The cone matures the second year. The seed is ripe about September 1 and dissemination commences soon afterwards. During dry seasons many more cones open up than in wet. Nearly half of them persist on the tree for several years,[1] opening gradually under the drying effect of heat and wind. Many cones that are on the ground do not open at all until scorched by fire. The process of seed dissemination of jack pine is thus almost continuous.

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[1] Report of Cloquet, Minn. Experiment Station, October, 1917, gives an average of 30 jack pine seed per cone as compared with 37 seeds per cone in Norway pine.

The small, light, jack pine seed with its relatively large wing is readily disseminated to considerable distances. It is probable that light winds, which are of frequent occurence in the range of jack pine during the season of dissemination, carry some of the seeds for distances of a quarter of a mile or more; but most of the seeds undoubtedly fall within 100 yards of the parent tree.

QUALITY OF SEED.

Freshly gathered samples of jack pine seed have shown germinating percentages of 95 or 100.[2] Samples from cones that had remained closed for some time indicated a germination of from 60 to 75 per cent. Seed in well-closed cones may retain its germinating capacity many years. The great quantity of seed produced and the high average percentage of germination explain to a degree the widespread distribution of this hardy species and its rapid regeneration on burned lands.

ESTABLISHMENT OF SEEDLINGS.

Under average natural conditions jack pine seed requires from 2 to 4 weeks for germination. Good seed, however, will germinate in 8 days under very favorable conditions of heat and moisture. If it is moist enough, the poorest sand will make a seed bed. After a a few weeks development of the root system the seedling becomes drought-resistant.

Reproduction is most plentiful on bare soil in the open, where the germinating seed strikes quickly into the mineral soil. Jack pine reproduction is usually excluded by other trees, weeds, and underbrush from better classes of seed bed, such as have a layer of well-decomposed humus. But a fire that destroys these and bares the mineral soil gives jack pine an excellent chance. In fact, fire is usually a necessary precursor of very dense jack pine reproduction, especially on good sites, because it clears the seed bed and opens up old cones. Where jack pine seeds in after a fire it is usually able to hold its own against other species. In northern Minnesota, however, if birch or aspen seed in simultaneously with it on a better class of soil, they usually crowd it out.

Jack pine seeding after a fire commonly produces an overstocked stand. Such a stand when 6 feet high would have from 5,000 to 10,000 trees to the acre; but, on account of the intolerance of the species, this number would rapidly diminish, so that the danger of stagnation is not very serious.[1] Under the shade of mature stands few jack pine seedlings appear, for their establishment and growth depend on their obtaining abundant light.

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[1] In the southern part of the range of jack pine in Wisconsin very few cones remain unopen on the trees.

[2] State Forester Schaaf, of Michigan, reports a 58 per cent germination for good, fresh seed.

The rate of growth of seedlings, especially seedlings of intolerant species, has much to do with the success or failure of the species, since it determines the amount of light they will receive in competition with other vegetation. Compared with other northern pines, jack pine grows rapidly, sometimes 6 inches or more the first year, 18 inches the first two years, and 3 feet the first three years.[2] On the the average, 1-year seedlings are 2 inches, 2-year-old seedlings 6 inches, and 4-year seedlings from 1 to 3 feet high. These last are not always high enough, however, to compete successfully with hardwood seedlings, brush, and weed growths of many kinds which are abundant on good soils.

SUSCEPTIBILITY TO INJURY.

FIRE.

Up to the age of 60 or 70 years fire is the greatest source of damage to jack-pine stands. These stands, occurring as they do on dry, sandy soils, are especially liable to fire damage after leaf litter and dead twigs have accumulated for several years. Fires in dense young stands often become crown fires, which burn with great fierceness and destroy the entire stand. In older and more open stands ground fires occur, which kill a few of the trees and lessen the vitality and resistance of those left.

Jack pine resists fire better than Norway and white pines because it grows more rapidly in diameter and height during its early years, and the young trees of a given age have thicker bark.

WIND, FROST, AND SNOW.

Jack pine trees do not often suffer from wind-throw where soil conditions have helped to develop a deep-going root system. On shallow and wet soils, however, the root system is flat and the tree is very susceptible to wind-throw. Where the trunks are tall and slender or where the trees have been weakened by insects or disease, severe storms cause considerable breakage.

Jack pine is not especially susceptible to damage from frost and snow, but heavy snowfalls and ice storms cause some injury to young slender saplings growing in dense stands. In the plantations of Nebraska and Kansas jack pine sometimes suffers from those snow and hail storms which come late in May and break off the leaders or new terminal shoots.

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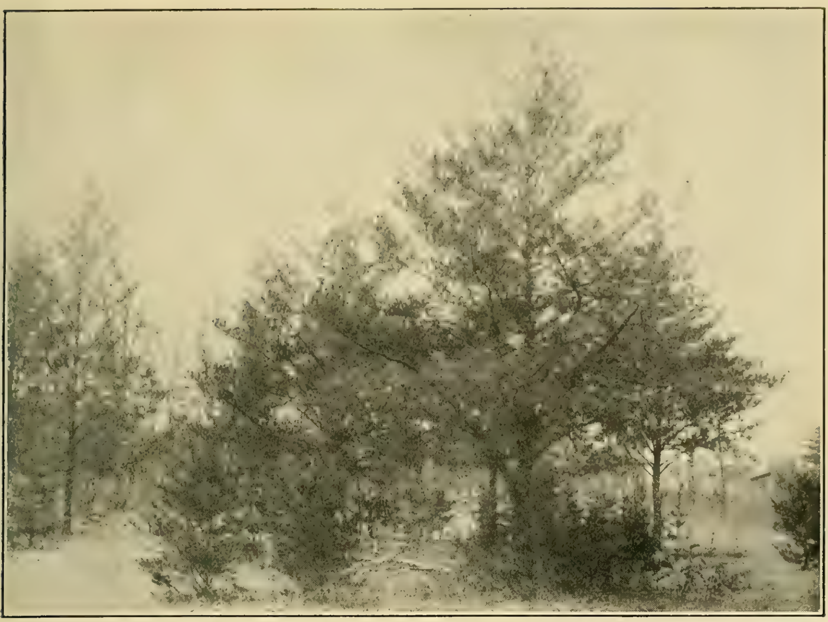
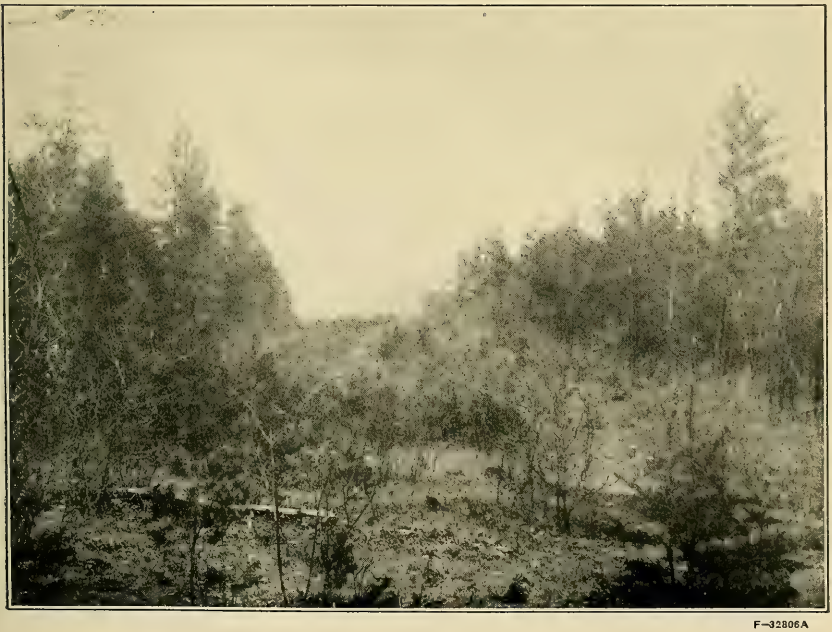
[1] Supervisor H. C. Hilton, of the Michigan National Forest, reports a case of complete stagnation of jack pine, a 20-year old stand containing from 50,000 to 100,000 trees per acre of an inch or less in diameter. Such cases, however, are very exceptional.

[2] Jack pine grows 2 to 3 whorls of branches each year (see fig. 4), while white and Norway pines only grow one.



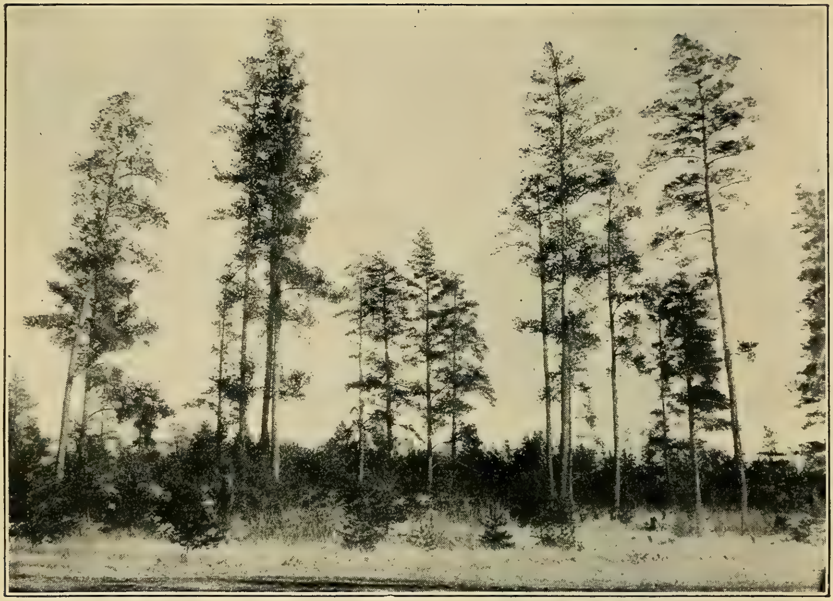
F-32805A

FIG. 1.—JACK PINE MOTHER TREE (9 INCHES IN DIAMETER BY 25 FEET IN HEIGHT) AND SEEDLINGS SPRUNG FROM IT (2 TO 8 FEET TALL).



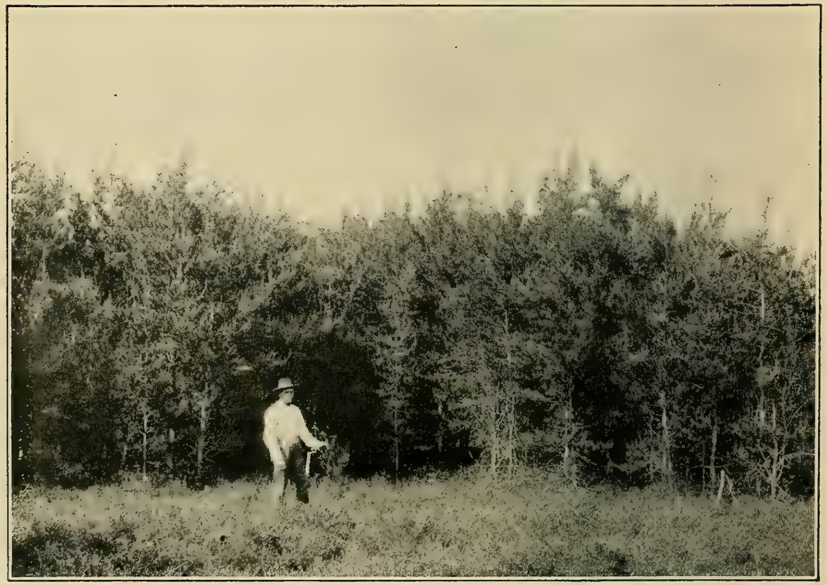
F-32806A

FIG. 2.—REPRODUCTION OF JACK PINE AND BUR AND BLACK OAK SPROUTS IN A STRIP CLEAR CUT SIX YEARS AGO.



F—31792

FIG. 1.—OVERMATURE JACK PINE ORIGINALLY GROWN IN DENSE STAND, BUT NOW OPEN THROUGH NATURAL THINNING, AND JACK PINE REPRODUCTION COMING UP UNDERNEATH. CROW WING COUNTY, MINN.



F—69122

FIG. 2.—REPRODUCTION OF JACK PINE AFTER CLEARING AND FIRES ON AN ABANDONED FARM IN THE JACK PLAINS REGION, MICHIGAN.

DISEASES.[1]

Jack pine stands are usually free of serious fungous diseases, but when they reach an age of from 60 to 90 years many of the trees become heart-rotted. The fungus that most often causes this condition is *Polyporus schweinitzii*, but *Trametes pini* is sometimes responsible for it.

The most common disease in jack pine is the gall-forming rust, *Cronartium cerebrum* (Peck) Hedgc. & Long. The injury done to young and old trees alike by this fungus is such that, in any system of forest management of jack pine, methods for its eradication should be considered. "It causes the death or early suppression of trees of tender years and seriously interferes with the development of more mature growth."[1]

The defect known as "witches' broom" is frequently present in jack pine crowns, especially in open stands on dry, sandy soils. This is a bushy growth of fine twigs from an affected point on a terminal shoot. The stimulus for this growth is probably furnished, in most cases, by some perennial fungus. The "witches' broom" precludes further development beyond the point of attack, and the increment of a badly infected tree falls off rapidly. The damage is not widespread, however, and in the aggregate is not serious.[1] Near the limits of its northern range the jack pine is subject to attacks by mistletoe, resulting also in the formation of "witches' brooms."

Several fungous saprophytes attack jack pine wood left in the forest and cause its quick decay. Dead trees usually become unsound within 2 or 3 years.

INSECTS.

Jack pine is rarely damaged by insects, except where the stand has been seriously weakened by fire, especially by fire occurring in the summer. According to Dr. A. D. Hopkins, of the Bureau of Entomology, United States Department of Agriculture, the living jack pine is often attacked and more or less seriously injured at the base and on the stems of saplings by bark weevils and bark beetles, on the buds and twigs by tip moths, and on the foliage by saw flies. The tip moth has attacked most of the jack pine in the plantations at Halsey, Nebr., reducing the height growth and causing minor crooks. The bark and wood of weakened, dying, and felled trees are subject to attack by the common wood-boring insects, which also cause pinhole and wormhole defects in the crude products.[2]

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[1] For a full discussion of the diseases of jack pine, see Bulletin No. 212, U. S. Department of Agriculture, "Observation on the Pathology of the Jack Pine," by James R. Weir, Forest Pathologist.

[2] Any evidence of serious injury to living trees or their products, known or supposed to be caused by insects, should be reported to a Federal or State entomologist with a request for advice as to the need of adopting measures for prevention or control.

SUPPLY OF JACK PINE TIMBER.

The largest supply of jack pine timber in the United States is in Minnesota, north of 46° of latitude. State Forester Cox in July, 1916, roughly estimated this supply at 5 billion board feet,[1] with 10 million cords of material obtainable from trees under 8 inches in diameter. He also stated it as his belief that jack pine in that State is probably growing more rapidly than it is being cut, although fires destroy annually a great deal of the young growth.

In 1898, Prof. Filibert Roth said [2] of the supply of jack pine in Wisconsin:

> At present it is not used to any extent, neither stumpage nor logs having real commercial value, except where used as fuel and for farm purposes. The stand of this pine, if taken down to 4 inches, is about 3½ billion feet, of which about half might be used for dimension stuff, while the rest could be employed as pulpwood.[3]

The supply of saw stuff has doubtless been considerably reduced since that time. With respect to trees suitable for cordwood and pulpwood, however, new growth has probably equaled the amount that has been cut in clearing and lumbering.

A recent compilation by the author of the Forest Resources of Michigan places the stand of possible jack pine saw timber at 1–1/5 billion board feet. There would be more than this much again of pulpwood. In New York and New England the stand of jack pine is negligible.

Bulletin 50 of the Canadian Forestry Branch contains an estimate for 1915 of from 7 to 8 billion board feet of jack pine timber in Manitoba, Saskatchewan, and Alberta.

The supply of jack pine is more nearly keeping pace with the annual cut than that of either Norway or white pine. On the one hand, the market for it is more limited because of the small size of its timber; and, on the other, it reproduces freely on cut-over or burned land formerly occupied by these more valuable species.

CHARACTERISTICS OF THE WOOD.

Superficially the wood of jack pine is similar to that of Norway and white pines. The sapwood is nearly white and the heartwood light brown to pale orange. In trees under 50 years of age the wood is mostly sap, the proportion gradually decreasing with age. Even in 100-year-old trees the sapwood often constitutes half the volume.

The wood is soft, light, a cubic foot of kiln-dried lumber weighing about 30 pounds, not strong nor tough, straight and rather coarse-grained, easily worked, easily split, and apt to warp and check in seasoning unless care is exercised. It is more resinous than white pine, but less so than the yellow pines of the South. The heartwood is fairly durable in contact with the ground, but the sapwood rots quickly.

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[1] A recent compilation by the author of the forest resources of Minnesota places the stand at 2½ billion board feet.

[2] Bulletin 16, Division of Forestry, U. S. Department of Agriculture.

[3] The stand of jack pine saw timber 8 inches and over in Wisconsin is placed in a recent compilation by the author at 1⅓ billion feet.

A comparison of the mechanical properties of jack pine and other species is shown in full in Bulletin 556, United States Department of Agriculture.[1] That bulletin gives the results of tests which show lower average values for jack pine than for Norway pine in cross bending, stiffness, and work to the maximum load perpendicular to the grain, and higher values in compression parallel and perpendicular to the grain, in hardness, and in shearing strength. The differences, however, are not great. As compared with white pine, jack pine shows somewhat higher average values in all the above properties except in stiffness and in cross bending, in which white pine averages slightly higher.

The specific gravity of oven-dry jack pine wood, based on volume when green, is 0.39, which is intermediate between Norway at 0.44 and white pine at 0.36. The weight of a cubic foot of air-dried wood of jack pine is 29 pounds, that of Norway is 34, and that of white pine is 27 pounds.

The structure of jack pine wood, in gross and microscopic characteristics, is not conspicuously different from that of other hard pines.

UTILIZATION.

Jack pine is used for railway ties, lumber, slack cooperage, pulpwood, mine timbers, poles, fencing, and fuel. (See Pls. XI and XII.)

RAILWAY TIES.

The greatest consumption of jack pine for railroad ties is in Canada, where in 1911 jack pine [2] replaced cedar as the leading species used, and 5½ million jack pine ties (38 per cent of all ties purchased) were bought by consumers at an average price of 41 cents. In 1914, 8,379,064 jack pine ties, comprising 43.2 per cent of all ties bought, were purchased in Canada at an average price of 43 cents. In the Lake States jack pine is used much less for ties than for lumber.

Ties can not be produced from trees under 10 inches in diameter breast high. Therefore, the proportion of the total stand of jack pine from which ties can be cut is relatively small and only the older trees can be used. Table 28 (appendix) indicates the number of ties it is possible to cut from trees of different sizes, and Table 9 shows the number of trees 10 inches and over in diameter in fully stocked stands of different ages.

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[1] "Mechanical Properties of Woods Grown in the United States," by J. A. Newlin and Thomas R. C. Wilson, of the Forest Products Laboratory.

[2] Including some lodgepole pine (*P. contorta*) from Alberta and British Columbia.

Untreated jack pine ties last from 6 to 8 years because they are cut from comparatively old trees that have a large proportion of durable heartwood. An increasing proportion of jack pine ties, however, is being creosoted, and these treated ties last from 15 to 20 years if they are not sooner rendered unusable by frequent spiking.

LUMBER AND SLACK COOPERAGE.

The chief use for the larger jack pine trees in the Lake States is for lumber. Where jack pine occurs either with Norway or white pine it is always cut with these species just as it comes. The larger and better trees are utilized chiefly for construction material, boards, siding, and box and slack cooperage material.

In Minnesota [1] most of the big mills cut at least a small quantity of jack pine. Perhaps 200 small mills cut jack pine, and in some cases nothing else, for use as box lumber and grain door boards. The annual cut is perhaps 200 million feet, and the cost of logs at the mills, from $7 to $9 per 1,000 board feet.

In Wisconsin [2] all mills, from the smallest to the largest, cut jack pine. It would be very difficult to get a figure on the amount cut by large mills, and impossible to get any estimate on the amount cut by the small mills, because in many instances the good jack pine goes in with Norway pine lumber.

The cost of jack pine at a sawmill varies from $10 to $15 per 1,000 board feet, depending on the location, business conditions, and size of the timber. In 1917, No. 3 and better jack pine lumber sold for $20 per 1,000 f. o. b. Duluth, Minn.

In Canada jack pine comprises about 1 per cent of the total annual lumber cut. Table 14 shows the cut of jack pine and the f. o. b. mill value of the lumber in the different provinces for the years 1913 and 1914.

TABLE 14—*Lumber cut and f. o. b. mill value of jack pine in Canada.*[3]

Province.	No. of active mills reporting.	Quantity.		Average value per M feet b. m.	
		1913	1914	1913	1914
		M ft b. m.	*M ft. b. m.*	*Dollars.*	*Dollars.*
Total all provinces	497	35,404	44,000	14.37	14.23
Ontario	47	24,297	17,890	14.51	15.00
Quebec	400	1,160	13,727	16.00	14.00
British Columbia	10	4,306	7,041	14.29	12.51
Alberta	22	2,237	4,488	15.83	14.58
New Brunswick	2	358	400	13.64	14.06
Manitoba	8	2,783	201	11.71	14.05
Saskatchewan	4	206	146	12.00	12.00
Nova Scotia	3	51	105	16.20	14.95
Prince Edward Island	1	6	2	12.50	20.00

[1] Letter from State Forester Cox, of Minnesota, July 17, 1916.
[2] Letter from State Forester Moody, of Wisconsin, July 31, 1916.
[3] From Bulletin 56 of the Canadian Forestry Branch.

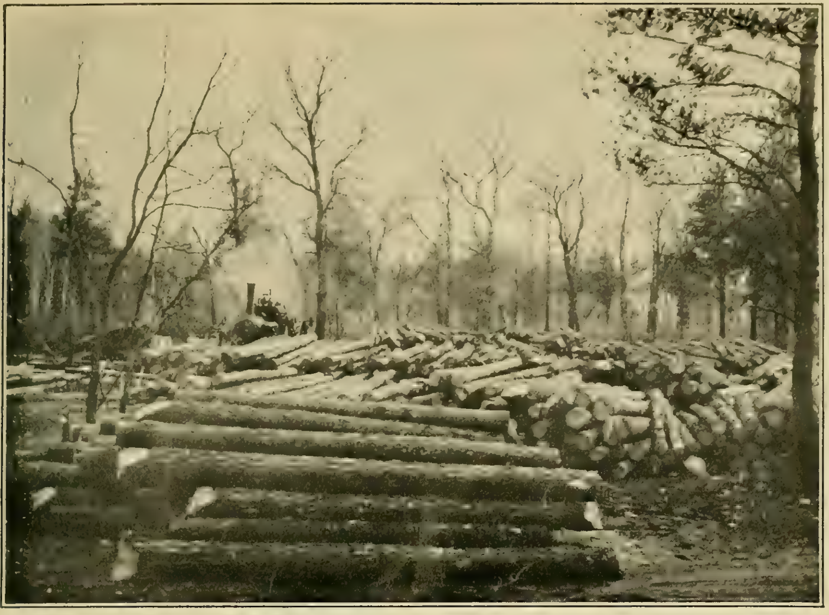

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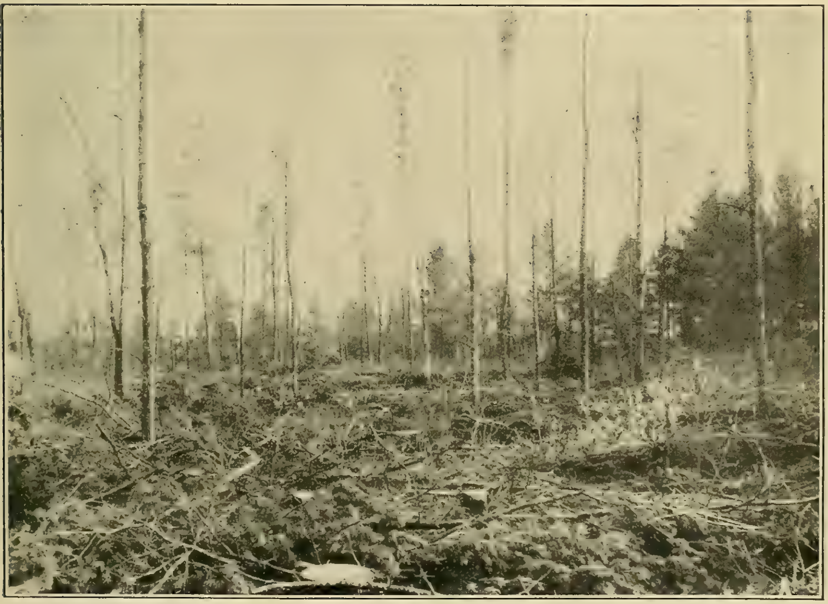
FIG. 1.—PORTABLE MILL OPERATION IN A 30 TO 40 YEAR OLD JACK PINE STAND. LOGS MOSTLY FROM 8 TO 10 FEET LONG BY FROM 4 TO 10 INCHES (AVERAGE 6) IN DIAMETER AT TOP END. SIXTEEN HUNDRED LOGS WERE ESTIMATED TO CUT 20,000 FEET, OR 80 LOGS PER 1,000 FEET. LOGS CUT MOSTLY INTO 2 BY 4 AND INCH BOARDS.

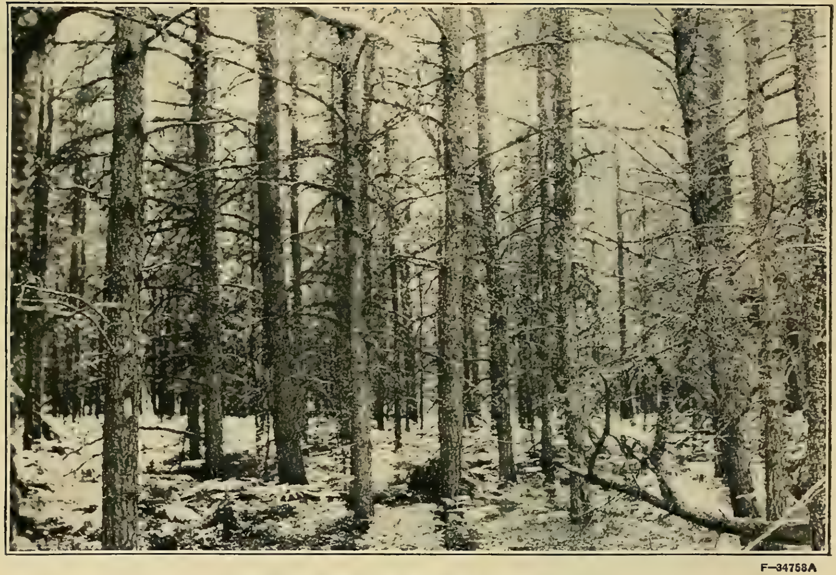


F—32817A

FIG. 2.—FORTY-YEAR-OLD STAND AFTER CLEAR CUT FOR PULPWOOD. SHOWS TREES TOO SMALL FOR PROFITABLE PULPWOOD CUTTING LEFT STANDING, BUT MOST OF WHICH WILL PROBABLY BE WIND-THROWN LATER ON.

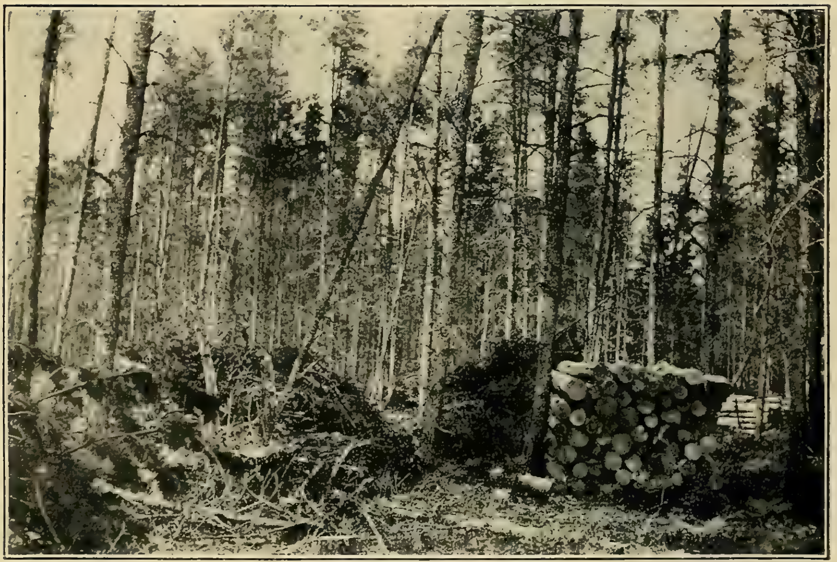
Danger of fire here is great on account of the unpiled and unburned slash.

LUMBERING OF DENSE, EVEN-AGED, JACK PINE STANDS.



F—34758A

FIG. 1.—STAND BEFORE CUTTING.



F—34757A

FIG. 2.—STAND BEING CUT.

DENSE, EVEN-AGED, 40 TO 50 YEAR OLD JACK PINE STANDS OF PULPWOOD SIZE, TREES 3 TO 9 INCHES IN DIAMETER, WITH 20 TO 25 CORDS PER ACRE.

In general, where Norway pine logs average from $12 to $14 per 1,000 board feet delivered at the mill, jack pine will average about $8.[1] In the winter of 1917, in Minnesota, jack pine logs sold as high as $12 and Norway pine at $17. The difference in price paid for jack and Norway pine in the log may be due partly to the fact that jack pine logs are smaller than the Norway pine, running sometimes 40 or 50 logs to the thousand. Many of the trees from the older jack pine stands in Minnesota cut out better lumber than it is usually supposed can be cut from this tree. In some cases at least 50 per cent of the season's run of jack pine goes into No. 2 and No. 3 boards and No. 1 and No. 2 dimension stock. As such it brings the same price as Norway pine, and is, in fact, often graded as lower grades of Norway and white pine.

Young stands of jack pine, too small for saw logs, are utilized for small slack cooperage, box boards, and crating. The cooperage material is used for pails, kegs, barrel headings, and a small amount for silos. In Michigan jack pine is used to a limited extent for shingles. Lath plants use the trees in the form of short bolts down to 3 or 4 inches in diameter at the top end. Young stands often yield large returns both on account of the great number of trees per acre and of this close utilization of small trees.

The number of board feet, mill scale, as given in Table 10, indicates the possibility of close utilization of jack pine in producing round-edge lumber for box and crating material. This method of utilization is feasible where portable mills are employed in dense, even-aged stands, and in this way a high yield of low-grade material is obtained at a small cost.

PULP.

Jack pine is suitable for chemical pulps made by using alkaline cooking liquors, either sulphate or soda. In this process it takes 2 cords of wood to produce a ton of sulphate pulp.

Jack pine is used for sulphate or kraft pulp in Michigan, Wisconsin, Quebec, and Ontario. In Quebec, in 1914, 16,746 cords of jack pine, at an average cost of $6.20 delivered, were used by three sulphate mills, while in Ontario in the same year 7,969 cords at $4 were used by one mill. There are three sulphate plants in Wisconsin and one in Michigan, and the outlook is good for additional plants of this kind in Canada and the Lake States. These plants should open up extensive markets for young second-growth jack pine trees too small for ties or lumber. In Wisconsin $5 per cord is the usual price paid for jack pine with bark left on delivered at the railroad. It costs the pulp mills about $8 per cord, delivered.

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[1] The following statement from a January, 1920, report of the supervisor of the Minnesota National Forest indicates how greatly prices and costs have changed since the above was written:

"A sale of standing jack pine timber on that Forest, made in 1919, brought $6.30 per 1,000 board feet for live and $3.15 for dead timber. The cost of logging this timber was about $20 per 1,000 feet, making a total cost of $23.15 to $26.30 for jack pine logs delivered on the landing, or double the cost of what white pine logs were 10 years ago. A few years ago, when the jack pine timber could have been logged for $5 to $8 per 1,000 feet, there was no sale for it."

Jack pine is used somewhat for ground wood pulp. "When combined with large proportions of sulphite jack pine ground wood pulp produces a satisfactory manila of a color other than white." [1] The Forest Products Laboratory is confident, from its experiments, that ground wood pulp from jack pine can be used in proportions well worth while in the manufacture of newsprint.

One of the big problems in the pulp industry in the Lake States is the obtaining of a supply of woods which can be converted at a reasonable cost into sulphite and ground wood pulp for newsprint paper, and which shall be accessible to the expensive plants already established. If jack pine can be used, the problem will be solved to a large extent for many of the established plants, because of the large supply of this wood in sizes suitable for pulp, its prolific reproduction, and its rapid growth. If the present prices for newsprint paper continue, methods will probably be developed which will make jack pine and other pines available for newsprint.

FUEL.

In many parts of its range, jack pine is the principal fuel, coal being scarce and its use limited. The estimated quantity of firewood used annually in the Lake States on farms alone is over 6,500,000 cords, and of this amount jack pine forms a large percentage. In many towns of 2,000 population and over the annual consumption is 2,500 cords and upward. Many of the local light and power companies use this species exclusively.

MINE TIMBER.

Jack pine in the round is used in considerable quantities in the Lake States for mine props, posts, and lagging. In northern Minnesota, jack pine timbers bring $18 per 1,000 feet Scribner Decimal C log scale, without cull for defects of any kind, f. o. b. main-line railroads.

POSTS AND POLES.

Considerable jack pine is used for posts, and, in the absence of better species, quite a little for short poles, from 20 to 30 feet in length. For these purposes it is particularly serviceable if it is well seasoned and painted with creosote or some similar preservative. The untreated timber does not last well in contact with the soil.

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[1] From Bulletin 343, U. S. Department of Agriculture, on "Ground Wood Pulp," by Thickens and McNaughton.

STUMPAGE VALUES.

Jack pine saw logs bring from $8 to $15 per 1,000 board feet delivered at the mills in the Lake States, and the stumpage is worth from $2 to $8 per 1,000, depending on the distance from the mill and the means of transportation. This is for logs 6 inches and over in diameter at the small end, scaled by log-rule measurement. Jack pine trees over 10 inches in diameter can often be most profitably cut into railroad ties or into poles, for which purposes its stumpage is worth from $5 to $10 per 1,000 board feet. Where close utilization for lath, boxes and crating, slack staves, and slats is pracitced, jack pine stumpage is worth from $1 to $5 per 1,000 feet of material actually cut out. For pulpwood, posts, and cordwood, where there is a market, jack pine is worth from 50 cents to $2 per cord, depending on its location.

TABLE 15.—*Stumpage values per acre of dense, even-aged stands of jack pine on site qualities "good" and "poor," figured for different values per cord and per 1,000 board feet.*

SITE QUALITY "GOOD."

Age.	Stumpage value per cord[1] of unpeeled wood.				Stumpage value per 1,000 board feet.					
					Mill scale.[2]			Scribner Decimal C.[3]		
	$0.50	$1.00	$1.50	$2.00	$1.00	$3.00	$5.00	$4.00	$6.00	$8.00
Years.										
20	$0.80	$1.60	$2.40	$3.20	$0.50	$1.50	$2.50	....	....	....
25	3.25	6.50	9.75	13.00	3.20	9.60	16.00	$1.20	$1.80	$2.40
30	6.80	13.60	20.40	27.20	6.90	20.70	34.50	2.80	4.20	5.60
35	11.05	22.10	33.15	44.20	10.50	31.50	52.50	5.60	8.40	11.20
40	14.00	28.00	42.00	56.00	13.20	39.60	66.00	9.20	13.80	18.40
45	15.80	31.60	47.40	63.20	14.90	44.70	74.50	15.20	22.80	30.40
50	17.10	34.20	51.30	68.40	16.30	48.90	81.50	20.80	31.20	41.60
55	18.20	36.40	54.60	72.80	17.40	52.20	87.00	24.80	37.20	49.60
60	19.20	38.40	57.60	76.80	18.50	55.50	92.50	27.60	41.40	55.20
65	20.05	40.10	60.15	80.20	19.60	58.80	98.00	30.40	45.60	60.80
70	20.90	41.80	62.70	83.60	20.60	61.80	103.00	32.80	49.20	65.60

SITE QUALITY "POOR."

25	0.65	1.30	1.95	2.60	0.70	2.10	3.50	....	....	....
30	2.35	4.70	7.05	9.40	2.20	6.60	11.00	....	....	....
35	4.35	8.70	13.05	17.40	4.00	12.00	20.00	....	....	....
40	6.50	13.00	19.50	26.00	6.20	18.60	31.00	....	....	....
45	8.35	16.70	25.05	33.40	8.10	24.30	40.50	1.60	2.40	3.20
50	9.95	19.90	29.85	39.80	9.60	28.80	48.00	3.20	4.80	6.40
55	11.40	22.80	34.20	45.60	10.90	32.70	54.50	6.00	9.00	12.00
60	12.75	25.50	38.25	51.00	12.20	36.60	61.00	10.00	15.00	20.00
65	13.95	27.90	41.85	55.80	13.40	40.20	67.00	15.20	22.80	30.40
70	15.05	30.10	45.15	60.20	14.50	43.50	72.50	19.60	29.40	39.20

The stumpage values assumed in the above calculations are such as are being paid in the Lake States to-day, or may reasonably be expected to be paid in the near future.

[1] With bark. [2] All trees 5 inches and over. [3] Trees 8 inches and over.

TABLE 16.—*Cost per acre of growing jack pine, figured for $2, $5, and $8 initial investment, including cost of land and cost of planting, if any, at compound interest.*

AT 6 PER CENT COMPOUND INTEREST.

Age.	Cost per acre, at 6 per cent compound interest.			Cost per acre, at 3 per cent compound interest.		
	$2.	$5.	$8.	$2.	$5.	$8.
Years.						
20	$8.98	$19.72	$30.44	$5.49	$11.72	$17.94
25	12.42	26.95	41.47	6.74	14.12	21.49
30	17.02	36.63	56.23	8.18	16.90	25.60
35	23.17	49.57	75.98	9.86	20.12	30.37
40	31.40	66.91	102.41	11.80	23.85	25.90
45	42.42	90.09	137.78	14.05	28.18	42.30
50	57.16	121.13	185.10	16.67	33.20	49.73
55	76.89	162.67	248.45	19.69	39.02	58.35
60	103.30	218.25	333.22	23.19	45.77	68.33
65	138.63	292.64	446.65	27.26	53.58	79.90
70	185.91	392.19	598.45	31.98	62.65	93.32

The following is allowed for annual expenses in the above calculations: Five cents per acre for administration and protection, plus 1 per cent of initial cost for taxes, at 6 per cent or 3 per cent compound interest. This amount is added to the cost of the initial investment to date.

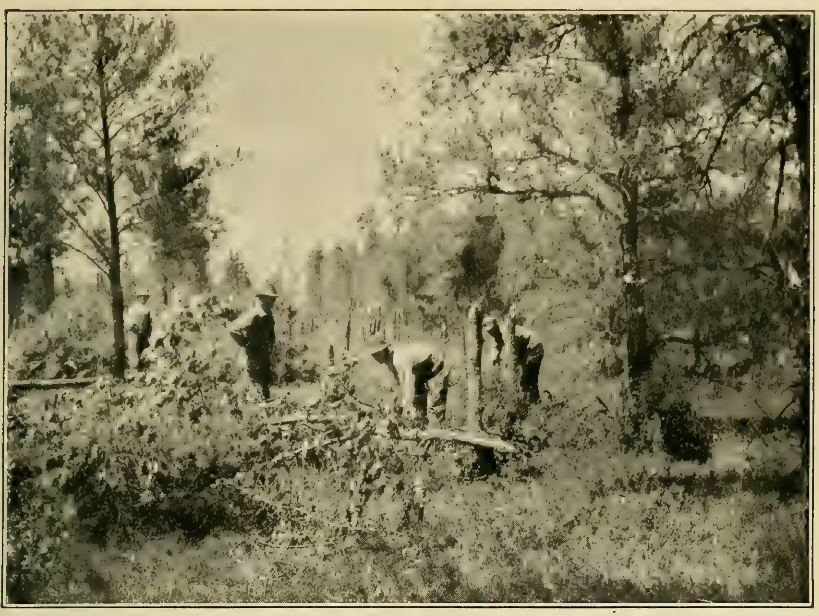
MANAGEMENT.

SUITABILITY OF JACK PINE FOR MANAGEMENT.

Jack pine is well suited for forest management for three reasons: (1) It thrives on poor soils; (2) it quickly reproduces itself after lumbering and fire, forming pure, densely stocked stands; and (3) it grows rapidly in its early years and soon attains sizes suitable for pulpwood, box boards, crating, small-dimension lumber, mine timbers, and slack-cooperage staves and heading. Its good growth on poor soils, unsuited to agricultural crops or on which more valuable kinds of tress do not readily seed up, suggests the possibility of utilizing large tracts of land which would otherwise be unproductive. The probability of this class of lands coming more and more under State or Federal control increases the importance of jack pine as a tree for forest management on a large scale.

Jack pine quickly seeds up poor soils and burned-over areas and makes them productive much sooner than would otherwise be the case. The more valuable Norway and white pines gradually seed in under the shelter of jack pine stands when the soil conditions improve. Wherever there is Norway or white pine reproduction underneath it to take its place, the jack pine should be eliminated after it reaches merchantable size.

Where jack pine occurs in mixture with Norway pine or other more valuable species on soils well suited to these latter, the natural reduction of jack pine that takes place with the increasing age of the stand should be allowed to go on. In some cases it may be advisable to reduce the proportion of jack pine by one or more cuttings to encourage the more valuable Norway pine in restocking the area and afterward to supplement the natural reproduction with



F—38621A

FIG. 1.—HIGH STUMPS CUT AS GUIDES IN LINING OUT FIRE LINE. THESE ARE REMOVED LATER SO THAT FURROWS CAN BE PLOWED.

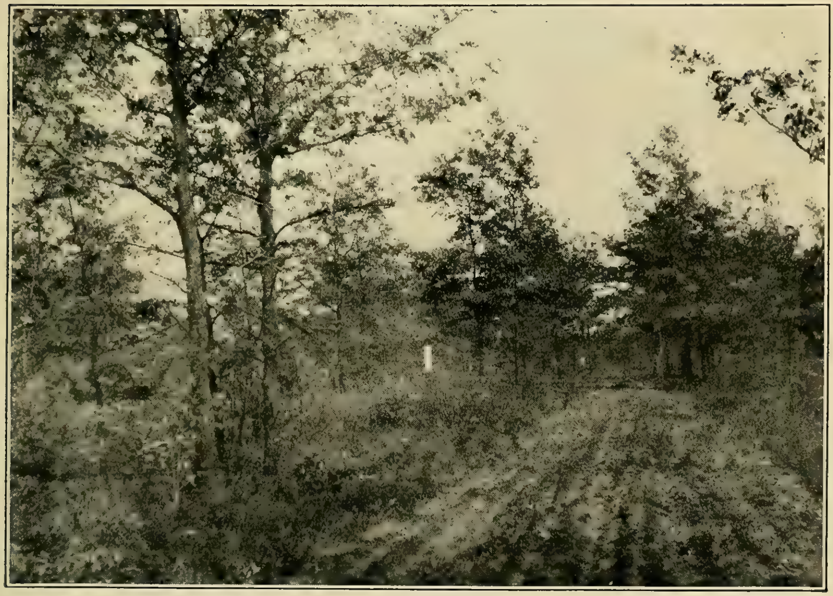


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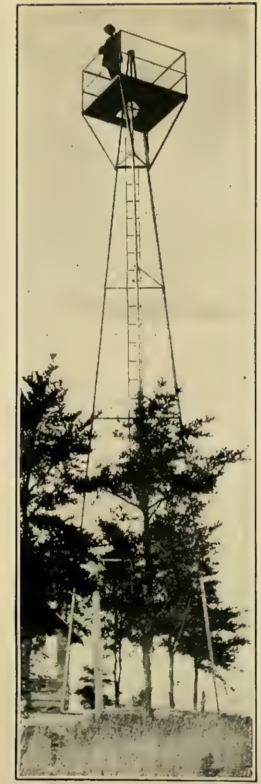
FIG. 2.—A COMPLETED FIRE LINE, SHOWING PLOWED FURROWS WITH THE LIGHT, SANDY SOIL EXPOSED.

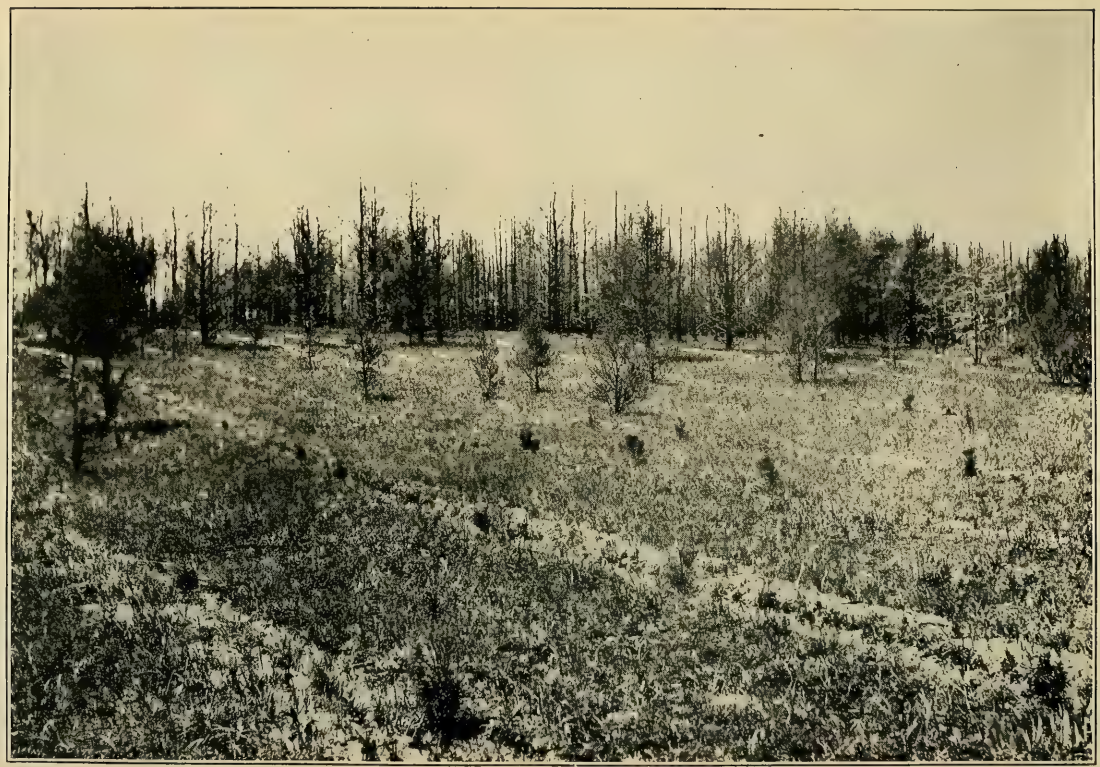
CONSTRUCTION OF FIRE LINES IN JACK PINE.



F–34761A

FIG. I.—THE BEST TYPE OF LOOKOUT TOWER.

It cost $125. One of these is sufficient for each 40,000 acres.



F–38031A

FIG. 2.—STAND OF JACK PINE TOTALLY DESTROYED BY FIRE, LOWER PENINSULA OF MICHIGAN.

The land has been planted to Norway pines, set in plowed furrows, spaced 8 feet apart and 8 feet between furrows.

a planting of Norway pine. Similarly, it will often be advisable to plant Norway or white pine on vacant areas where the soil is suitable, which otherwise might become seeded up to jack pine by natural reproduction, as is being done in parts of Michigan. On poorer soils, however, where Norway or white pine has a poor chance of success, natural jack pine reproduction should always be encouraged.

The possible returns in growing jack pine may be estimated from Table 15, which gives the stumpage value per acre at different ages, figured for different values per cord and per 1,000 board feet, taken in connection with Table 16, which gives the cost per acre of growing such stands. Thus, on "good" quality jack pine land the stumpage value per acre of a 40-year-old stand at $1 per cord amounts to $28, as shown by Table 15. Reference to Table 16 shows that in 40 years, with money at 6 per cent and with an original investment of only $2 per acre, at which cost it would very rarely be possible to secure adequately stocked stands, the cost would be $31.40, or $3.40 more than the stumpage value. On the other hand, money at 3 per cent would admit of an original cost of $8 per acre and give a profit of $2.10 per acre above the 3 per cent interest earned on all money invested. In general, raising jack pine is at present a losing investment as compared with other investments at 6 per cent, but a very good one as compared with others at 3 per cent. At this latter rate of interest the State or Federal government would be fully justified in growing it on lands unsuited to agricultural crops or to more valuable species of trees.

ROTATION.

A short rotation for jack pine is the most practicable for securing the best financial returns and the reproduction of a new stand with the least difficulty. A comparison of Tables 14 and 15 indicates the financial advisability of a short rotation. Thus, with a stumpage value of $5 per 1,000 board feet mill scale, and with $5 original investment at 6 per cent on "good" quality of jack pine land, the best financial rotation appears to be around 35 years. When trees are of this age the stumpage value would be $52.50 per acre, and the cost, at 6 per cent interest on all money invested, only $49.57.

On lands under public control, where the financial return is secondary to the object of making otherwise waste land productive, a rotation of 60 years may be advisable, which would allow the production of ties and lumber as well as mine timbers, box boards, and pulpwood.

PROTECTION.

Since fires, even if not severe enough to kill the trees outright, practically always damage stands by impoverishing the soil, injuring and weakening individual trees, and reducing their resistance to insects and fungi, the subject of fire protection is of prime importance in management. Reasonable assurance of protection is necessary before any expense in planting or management is warranted. To be adequate, the plan for fire protection should include provisions for patrol during the seasons when fire is a menace, the establishment and maintenance of fire lanes, the disposition of the slash resulting from thinnings or logging, and, on large tracts, lookouts and telephones. (See Pls. XIII and XIV.) An accumulation of logging slash is a menace to any live timber near it, not only because of its inflammability, but also because it may harbor destructive insects. Brush may best be disposed of by burning. Cutting in the fall and winter and burning the slash in piles as the logging proceeds is an effective preventive of insect infestation. Fire lanes, properly laid out, could be used in many cases as a means of dividing the forest into cutting series or blocks for utilization purposes and these lands would make one block accessible without slashing into another adjacent to it.

Danger from windfall may be lessened by cutting first on the lee side and proceeding in the direction from which the prevailing winds blow. In this way the interior of the stand is not opened to the sweep of the wind. Also, a short rotation will involve less windfall than a long one.

NATURAL REPRODUCTION.

The cutting of jack pine stands to encourage natural reproduction of the species may be accomplished in either one of two ways. The first method is that of clean cutting the mature stand either in strips or patches 100 yards or less in width. Reproduction would then take place from seed already on the ground or blown from the adjacent woods. The second method is that of a general clean cutting, leaving only from 5 to 10 scattered seed trees to the acre or, preferably, 2 or 3 groups of from 3 to 5 trees each. (See Pl. IX.)

To make sure of getting jack pine reproduction on the National Forests in northern Minnesota, it is sometimes considered necessary to lop the tops of the trees that have been cut and scatter the brush, which is burned in the spring as soon as it is dry enough. This causes cones on the ground to open and let out their seed. Also, the seedbed is prepared by the partial exposure of the mineral soil. On shallow soils with rock near the surface, brush should be burned in winter while snow is on the ground, so that the soil covering will not be disturbed. Fires should always be carefully controlled and be kept away from seed trees and adjacent timber Where overstocking of jack pine results, as is common after fires, the stand may be thinned out at a minimum expense within the first five years after the reproduction takes place. Natural reproduction and thinning would be less expensive than planting.

On the Michigan National Forests fire is not considered necessary in order to secure natural reproduction. This is because poorer soil conditions are found here than in northern Minnesota, and there is a much less vigorous growth of popple and white birch. The general policy here is to cut all merchantable trees, pile and burn the brush, and rely for reproduction on the seed that is already on the ground, or that may come either from the trees left after cutting or from trees on adjacent uncut areas.

PLANTING AND SOWING.

The cost of planting jack pine nearly equals that for white and Norway pines. Therefore, the extensive planting of this species does not seem warranted except on the poorest soils where these better trees will not grow. Even here, the ease with which natural reproduction is secured makes planting unnecessary in the majority of cases. For forest planting on relatively arid soils both inside and outside its natural range, for windbreaks, and for the fixation of moving sand, jack-pine may be the best tree to use. On severe exposures in the sand hills of Nebraska, for example, jack pine plantations have been eminently successful, while those of Scotch, Norway, and western yellow pines, Douglas fir, and arborvitæ have failed. (See Pl. XV.)

The recently adopted policy of the Public Domain Commission of Michigan provides for the planting each year of from 4,000 to 5,000 acres of waste sandy-plains land to forest trees, of which the State Forester[1] says from 20 to 33 per cent will probably be jack pine. It is here to be used largely as a filler for Norway and white pines, and planted from 5 to 6 feet apart in ploughed furrows, with 6 feet between the furrows. The National Forests in Michigan and Minnesota contain large areas of jack pine land. Wherever jack pine reproduces naturally, the Forest Service is glad to have it do so and in this way save the expense of planting. But the present Forest Service practice is not to plant jack pine on vacant land on these Forests, as it is believed none of this land is too poor to grow the much superior Norway pine. (See Pl. XIV, fig. 2.)

Nursery-grown stock is almost always used in planting out, wild stock being only occasionally collected for this purpose. Experimental planting of jack pine shows that on poor sites, such as those found in the sand hills of Nebraska, the best results are obtained from the use of 3-year-old stock which has been two years in the seed bed and one year in the transplant bed. This material can be raised at a cost of from $3.50 to $4 per thousand, including seed, preparation of beds, and subsequent care, while the collected wild stock costs about $5 per thousand. On Michigan State forests, however, good success has been secured from planting 2-year seedlings, and this was done at a total cost of $6 or less per acre for stock and planting. The State Forester[1] says:

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[1] Marcus Schaaf.

> Two-year seedlings are so much cheaper than transplants, both as to material cost and labor of planting, and the death rate in plantations made with them is so small that we do not think that the increased cost of transplants is justifiable in planting on a large scale.

The most favorable time for planting in the spring is from the middle of April to the middle of May, and in the fall during the months of September and October.

The artificial establishment of jack pine stands by sowing the seed broadcast over the proposed site has been attempted, but, although the experiment was tried under many different conditions, it never met with much success. These experiments included spring and fall sowing and broadcasting on the snow in late winter. Some of the seeds germinated and became quite thrifty plants early in the spring, but were killed by the excessive heat during June and July.

The results of sowing and planting experiments in the northern half of the Lower Peninsula of Michigan indicate that planting home-grown nursery stock, and, in exceptional cases, thrifty 2 to 3 year old wild stock, promises the most satisfactory results.

THINNINGS.

The future value of dense young stands of jack pine may be greatly increased by thinning out the less promising and releasing the large and promising trees from competition for light and soil moisture, and in this way concentrating the growth energy of the stand into a smaller number and the best trees. In many cases some of the better trees should be cut, where these grow too close together, in order to establish a uniformly thinned stand, with the crown of each tree practically free on all sides, or barely touching its neighbors.

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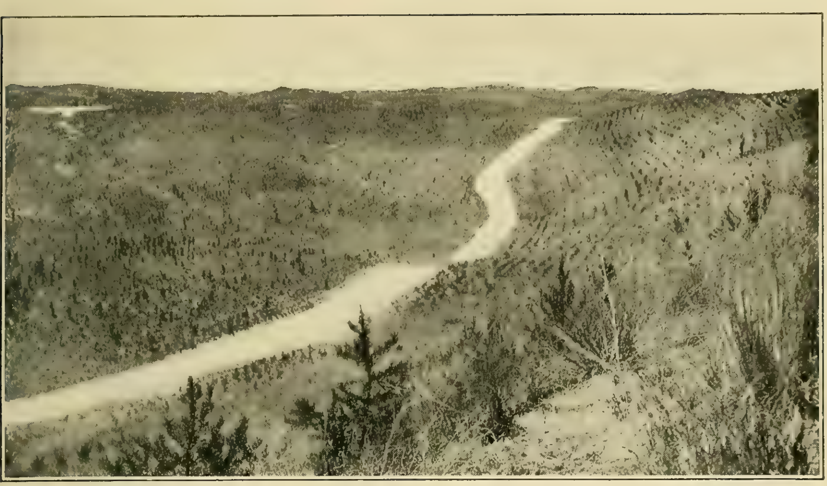
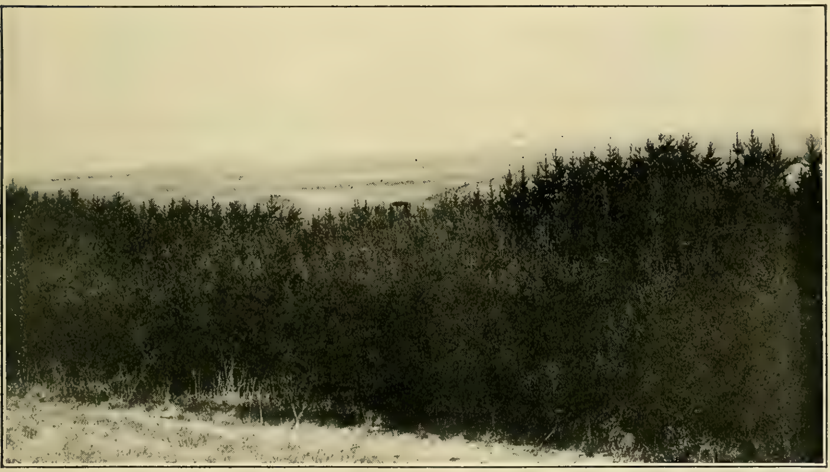
[1] Marcus Schaaf.



F—37557A

FIG. 1.—FIVE-YEAR-OLD JACK PINE PLANTATION TO RIGHT OF FIRE LINE, AND 9 TO 11 YEAR OLD YELLOW PINE PLANTATION TO THE LEFT OF FIRE LINE, IN THE DISMAL RIVER DIVISION OF THE NEBRASKA NATIONAL FOREST.

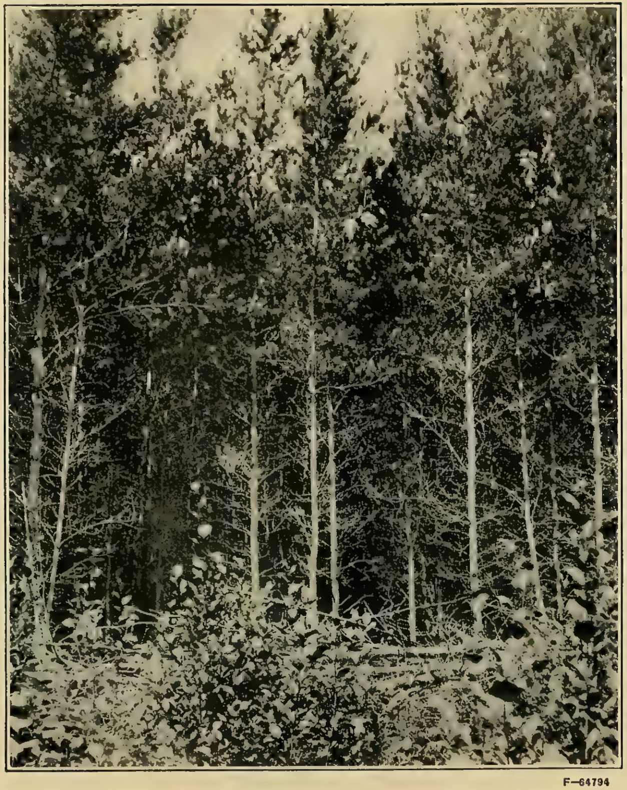
Jack pine survived and grew on more severe exposures where Scotch, Norway, and western yellow pines, Douglas fir, and arborvitæ failed.



F—22169

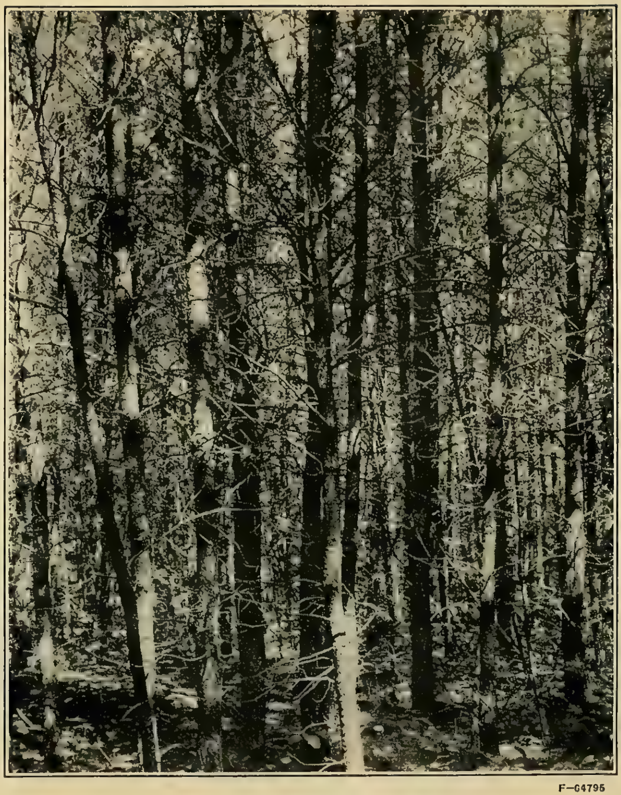
FIG. 2.—FIFTEEN-YEAR-OLD PLANTATION IN HOLT COUNTY, WHERE REAL FOREST CONDITIONS HAVE BECOME ESTABLISHED.

PLANTATIONS OF JACK PINE IN THE SAND HILLS OF NEBRASKA.



F—64794

FIG. 1.—EXTERIOR VIEW.



F—64795

FIG. 2.—INTERIOR VIEW.

DENSE 20-YEAR-OLD STAND OF JACK PINE ON CLAY SOIL IN NEED OF THINNING. HUBBARD COUNTY, MINN.

Table 31 (appendix) gives the yields obtained from thinnings of well-managed stands of Scotch pine in Europe. A comparison of these with the final yields given in Table 30 indicates cumulative intermediate returns, on quality III or average sites, of 5 to 40 per cent on any rotation between the ages of 30 and 50 years, inclusive. Similar results could probably be secured from the management of jack pine where the market conditions were favorable for utilizing the product of such cuttings.

Instead of clean cutting young jack pine stands for cordwood, as is often done, owners would do well to get their firewood by thinning their stands and allow the better trees to remain and produce a crop of timber valuable for purposes other than fuel. Jack pine stands should preferably be thinned as early as 20 years of age. (See Pl. XVI.) Thinnings to be effective should be severe, leaving the crowns of the trees fully isolated on all sides for a space of 5 to 10 feet. There would be considerably more danger from windfall and windbreak to trees left after severe thinnings in older stands than in younger—an important reason for thinning before the stand is 25 years old.

Very dense, overstocked sapling stands, from 6 to 8 feet high and from 5 to 6 years in age, such as are liable to stagnate, can be beneficially thinned by clearing of parallel lanes about 6 feet wide at from 8 to 12 foot intervals through the stand, and also thinning out trees in the rows to be left, or the stand may be thinned in two series of clear-cut parallel lanes at right angles to each other. From 800 to 1,200 trees to the acre, or 5 to 7 to the square rod, is a sufficient number to leave after thinning, provided some trees are left on every square rod of area and no large gaps are made in the stand. The saplings cut should be dragged out of the thicket and burned as a fire-protective measure and to prevent insects from breeding in the slash.

Clearing of lanes in overstocked sapling stands from 3 to 5 feet in height could be accomplished with greater ease than in taller stands, as brush scythes and brush hooks could be used, but would be inadvisable on poor dry soils where the establishment of a soil cover and good humous conditions are important. Lanes cut in such stands should, in general, be about the same width as the height of the stand.

APPENDIX.

BIBLIOGRAPHY.

DATA ON WHICH THIS BULLETIN IS BASED.

(*1*) *Field measurements in Forest Service files.*

Author.	Location.	Year.	Number taken.
Stem analyses:			
Chapman, H. H	Hubbard County, Minn	1905	606 analyses of trees 2 to 17 inches in diameter.
Benedict, J. St. J	Cass County, Minn	1912	52 analyses of trees 7 to 16 inches in diameter.
Sherrard, T. H	Roscommon and Crawford Counties, Mich.	1901	150 analyses of trees 3 to 13 inches in diameter.
Sample plots:			
Chapman, H. H	Hubbard County, Minn	1905	128 plots, 90.2 acres.
Sterrett, W. D	Adams County, Wis	1917	12 plots.
Valuation surveys:			
Sherrard, T. H	Roscommon and Crawford Counties, Mich.	1901	100 acres, "Jack pine plain."

(*2*) *Manuscripts in the Forest Service files.*

"Report on the Study of Tie Production for the Northern Pacific Railroad,'' by Prof. H. H. Chapman, 1905.

"Jack Pine," by J. St. J. Benedict, 1914.

"Silvical Study of the Jack Pine," by L. L. White, 1906.

"Reforestation Policy for the Michigan and Marquette National Forests,'' by R. Zon, 1911.

"Forest Planting in Northern Michigan,'' by W. B. Piper, 1912.

Silvical Report, Michigan National Forest, by W. B. Piper, 1912.

Silvical Report, Superior National Forest, by J. A. Fitzwater, 1912.

"Jack Pine,'' by C. A. Cecil, of the Superior National Forest, 1918.

(*3*) *Publications.*

"Jack Pine,'' Silvical Leaflet 44, Forest Service, 1909.

"Jack Pine in Western Ontario,'' by L. M. Ellis, in Forestry Quarterly, March, 1911.

Report of the Michigan Forestry Commission, 1902, in articles by T. H. Sherrard, Prof. Filibert Roth, and others.

"Forestry Conditions in Wisconsin,'' by Filibert Roth, Bulletin 16, Division of Forestry, U. S. Department of Agriculture.

Bulletins of the Canadian Forestry Branch.

TABLES.

TABLE 17.—*Proportion of the occurrence of jack, Norway, and white pine stands on different soils in northern Minnesota classified according to the prevailing size of their soil particles.*[1]

Class of soil.	Jack pine stands.	Norway pine stands.	White pine stands.
	Per cent.	*Per cent.*	*Per cent.*
Fine gravel, 2.0 to 1 mm	1.1	0.4	0.0
Coarse sand, 1 to 0.5 mm	61.0	3.7	3.3
Medium sand, 0.5 to 0.25 mm	30.3	12.0	4.6
Fine sand, 0.25 to 0.1 mm	3.3	62.9	16.2
Very fine sand, 0.1 to 0.05 mm	3.7	11.5	43.4
Silt, 0.05 to 0.005 mm	1.9	6.7	26.1
Clay, 0.005 mm	1.7	2.8	6.4
Total	100.0	100.0	100.0

[1] From unpublished preliminary report on Norway pine in Minnesota by H. H. Chapman. Based on mechanical analysis by the Bureau of Soils of a large number of soil samples from different jack, Norway, and white pine stands.

TABLE 18.—*Average width of crowns of predominant jack-pine trees of different ages and diameters, with enough light for good crown development, and growing in comparatively dense, even-aged stands.*

[Measurements by H. H. Chapman in Hubbard County, Minn., 1905.]

Age.	Site quality "good."			Site quality "poor."		
	Average diameter breast high.	Width of crown.	Basis.	Average diameter breast high.	Width of crown.	Basis.
Years.	*Inches.*	*Feet.*	*Trees.*	*Inches.*	*Feet.*	*Trees.*
10	1.8	7		1.1	3	
20	5.5	11	1	3.9	6	
30	7.9	14	9	5.9	9	5
40	9.4	16	38	7.4	11	19
50	10.8	18	18	8.7	12	3
60	12.0	22	4	9.9	14	35
70				10.9	15	13
80				11.8	16	8
90					18	5
100					19	1
110					22	
120					24	
130					27	2
			70			91

TABLE 19.—*Double bark thickness, at diameter breast high, of jack pine in Minnesota.*

Diameter breast high.	Hubbard County, Minn.				Cass County, Minn.	
	Trees in dense stand.		"Isolated" or partly "isolated" trees. Bark.	Basis.	Bark.	Basis.
	Bark.	Basis.				
Inches.	*Inches.*	*Trees.*	*Inches.*	*Trees.*	*Inches.*	*Trees.*
2	0.23	15	....	....	....	....
3	.30	28	....	....	....	....
4	.38	66	....	....	0.39	....
5	.46	75	0.49	3	.43	....
6	.54	80	.61	8	.47	....
7	.63	85	.72	9	.52	1
8	.72	57	.84	13	.56	4
9	.82	47	.94	7	.61	8
10	.92	43	1.05	5	.67	16
11	1.03	22	1.15	7	.73	7
12	1.14	13	1.25	4	.80	10
13	1.26	6	1.34	1	.87	3
14	1.37	6	1.43	1	.94	1
15	1.48	1	1.51	....	1.02	1
16	1.59	2	1.59	2	1.09	1
17	1.70	3	....	....	1.17	....
18	1.79	....	....	....	1.25	....
19	1.87	....	....	....	1.33	....
20	1.94	....	....	....	1.41	....
		549		60		52

TABLE 20.—*Average thickness of bark at different heights above the ground in predominant jack pine trees in Hubbard County, Minn.*

[Trees 22 to 102 years old. Measurements by H. H. Chapman, 1905.]

Diameter breast high.	Height above ground (feet).								Basis.
	1	9	17	25	33	41	49	57	
Inches.									*Trees.*
5	0.60	0.18	0.12	0.10	....	....	....	....	2
6	.64	.23	.17	.12	0.08	....	....	....	8
7	.70	.26	.19	.14	.10	0.06	....	....	15
8	.76	.29	.21	.16	.12	.09	....	....	16
9	.83	.32	.23	.18	.15	.12	....	....	33
10	.91	.35	.26	.21	.17	.14	0.09	....	37
11	.96	.38	.28	.23	.18	.15	.10	....	21
12	1.01	.41	.31	.25	.20	.17	.11	....	12
13	1.05	.44	.34	.27	.22	.18	.12	....	9
14	1.09	.47	.37	.29	.23	.20	.14	0.11	3
15	1.12	.50	.39	.31	.25	.22	.17	.14	1
16	1.14	.52	.41	.33	.27	.24	.20	.17	2
17	1.16	.54	.43	.35	.29	.26	.23	.20	3
									162

TABLE 21.—*Taper of jack pine trees of different diameters and heights, showing diameter inside bark at different heights above the ground.*

[Based on measurements by H. H. Chapman in Hubbard County, and a few by J. St. J. Benedict in Cass County, Minn., of trees cut in dense, even-aged stands. Measurements taken on jack pine in Roscommon County, Mich., indicated the same taper as given in this table for trees of different diameters and heights.]

20-FOOT TREES.

Diameter breast high.	Height above ground (feet).								Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	
	Diameter inside bark (inches).								
Inches.									*Trees.*
2	2.0	1.9	1.8	1.8	1.4	0.4			9
3	3.1	2.9	2.8	2.7	2.3	.7			4
4	4.1	3.9	3.8	3.6	3.1	1.1			
5	5.1	4.9	4.7	4.6	3.9	4.1			1
6	6.1	5.9	5.7	5.5	4.7	1.7			
7	7.2	6.9	6.6	6.4	5.5	2.0			
8	8.2	7.8	7.6	7.3	6.3	2.3			
									14
30-FOOT TREES.									
2	2.0	1.9	1.8	1.8	1.6	1.2	0.5		6
3	3.1	2.9	2.8	2.7	2.4	1.7	.7		22
4	4.1	3.9	3.8	3.6	3.2	2.2	.9		17
5	5.1	4.9	4.7	4.6	4.0	2.8	1.1		7
6	6.1	5.9	5.7	5.5	4.8	3.3	1.3		8
7	7.2	6.9	6.6	6.4	5.6	3.9	1.5		5
8	8.2	7.8	7.6	7.3	6.4	4.4	1.7		
9	9.2	8.8	8.5	8.2	7.2	5.0	1.9		
10	10.2	9.8	9.5	9.1	8.0	5.5	2.1		
									65
40-FOOT TREES.									
2	2.0	1.9	1.8	1.8	1.7	1.7	1.3	0.7	
3	3.1	2.9	2.8	2.7	2.5	2.2	1.7	.8	2
4	4.1	3.9	3.8	3.6	3.3	2.8	2.1	1.0	41
5	5.1	4.9	4.7	4.6	4.2	3.4	2.5	1.2	31
6	6.1	5.9	5.7	5.5	5.0	4.1	2.9	1.4	25
7	7.2	6.9	6.6	6.4	5.8	4.7	3.3	1.6	24
8	8.2	7.8	7.6	7.3	6.6	5.3	3.7	1.7	21
9	9.2	8.8	8.5	8.2	7.4	5.9	4.1	1.9	14
10	10.2	9.8	9.5	9.1	8.2	6.5	4.5	2.1	6
11	11.2	10.8	10.4	10.1	9.0	7.1	4.9	2.2	3
12	12.2	11.7	11.4	11.0	9.8	7.7	5.3	2.4	1
13	13.2	12.7	12.3	11.9	10.6	8.3	5.7	2.6	
14	14.2	13.6	13.2	12.8	11.3	8.9	6.1	2.7	
									168

TABLE 21.—*Taper of jack pine trees of different diameters and heights, showing diameter inside bark at different heights above the ground*—Continued.

50-FOOT TREES.

Diameter breast high.	Height above ground (feet).										Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	
	Diameter inside bark (inches).										
Inches.											*Trees.*
4	4.1	3.9	3.8	3.6	3.5	3.2	2.8	2.1	1.3	....	8
5	5.1	4.9	4.7	4.6	4.4	3.9	3.3	2.5	1.4	....	34
6	6.1	5.9	5.7	5.5	5.2	4.6	3.9	2.9	1.6	....	39
7	7.2	6.9	6.6	6.4	6.0	5.3	4.4	3.3	1.8	....	36
8	8.2	7.8	7.6	7.3	6.8	6.0	4.9	3.7	2.0	....	17
9	9.2	8.8	8.5	8.2	7.6	6.7	5.5	4.0	2.2	....	14
10	10.2	9.8	9.5	9.1	8.4	7.4	6.0	4.4	2.5	....	14
11	11.2	10.8	10.4	10.1	9.2	8.0	6.6	4.8	2.7	....	8
12	12.2	11.7	11.4	11.0	10.0	8.7	7.2	5.2	2.9	....	6
13	13.2	12.7	12.3	11.9	10.8	9.3	7.7	5.6	3.1	....	2
14	14.2	13.6	13.2	12.8	11.6	10.0	8.2	6.0	3.3	....	1
15	15.1	14.6	14.1	13.7	12.4	10.7	8.8	6.4	3.5	....	....
16	16.1	15.5	15.0	14.6	13.2	11.3	9.4	6.8	3.7	....	....
17	17.0	16.4	15.9	15.5	14.0	12.0	9.9	7.2	3.9	....	....
18	18.0	17.3	16.8	16.4	14.7	12.7	10.5	7.6	4.1	....	....
											179
					60-FOOT TREES.						
6	6.1	5.9	5.7	5.5	5.2	4.8	4.3	3.7	2.9	1.7	21
7	7.2	6.9	6.6	6.4	6.1	5.5	4.9	4.2	3.3	1.9	29
8	8.2	7.8	7.6	7.3	6.9	6.2	5.6	4.8	3.7	2.2	30
9	9.2	8.8	8.5	8.2	7.7	6.9	6.2	5.3	4.0	2.4	24
10	10.2	9.8	9.5	9.1	8.6	7.7	6.9	5.9	4.4	2.6	26
11	11 2	10.8	10.4	10.1	9.5	8.5	7.5	6.4	8.4	2.8	10
12	12.2	11.7	11.4	11.0	10.3	9.2	8.2	6.9	5.2	3.1	6
13	13.2	12.7	12.3	11.9	11.2	10.0	8.8	7.4	5.5	3.3	4
14	14.2	13.6	13.2	12.8	12.0	10.7	9.5	7.9	5.9	3.5	1
15	15.1	14.6	14 1	13.7	12.8	11.5	10.1	8.4	6.3	3.7	....
16	16.1	15.5	15.0	14.6	13.6	12.2	10.8	9.0	6.7	4.0	....
17	17.0	16.4	15.9	15.5	14.4	13.0	11.4	9.5	7.1	4.2	1
18	18.0	17.3	16.8	16.4	15.2	13.7	12.0	10.0	7.5	4.4	....
19	19.0	18.2	17.7	17.3	16.0	14.4	12.7	10.5	7.8	4.6	....
20	19.9	19.1	18.6	18.2	16.8	15.1	13.4	11.1	8.2	4.9	....
											152

TABLE 21.—*Taper of jack pine trees of different diameters and heights, showing diameter inside bark at different heights above the ground*—Continued.

70-FOOT TREES.

Diameter breast high.	Height above ground (feet).												Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	
	Diameter inside bark (inches).												
Inches.													*Trees.*
6	6.1	5.9	5.7	5.5	5.3	4.9	4.6	4.2	3.5	2.7	1.7	....	....
7	7.2	6.9	6.6	6.4	6.2	5.7	5.3	4.8	4.1	3.2	2.0	....	1
8	8.2	7.8	7.6	7.3	7.1	6.5	6.0	5.4	4.7	3.6	2.3	....	3
9	9.2	8.8	8.5	8.2	8.0	7.3	6.7	6.0	5.2	4.0	2.5	....	6
10	10.2	9.8	9.6	9.1	8.8	8.1	7.4	6.6	5.7	4.4	2.8	....	14
11	11.2	10.8	10.4	10.1	9.7	8.9	8.1	7.3	6.2	4.8	3.1	....	10
12	12.2	11.7	11.4	11.0	10.5	9.6	8.8	7.9	6.7	5.2	3.4	....	8
13	13.2	12.7	12.3	11.9	11.4	10.4	9.5	8.5	7.2	5.6	3.7	....	2
14	14.2	13.6	13.2	12.8	12.2	11.2	10.2	9.1	7.7	6.0	4.0	....	4
15	15.1	14.6	14.1	13.7	13.1	12.0	10.9	9.7	8.2	6.4	4.3	....	1
16	16.1	15.5	15.0	14.6	13.9	12.7	11.6	10.3	8.7	6.8	4.6	....	4
17	17.0	16.4	15.9	15.5	14.8	13.5	12.3	10.9	9.2	7.2	4.9	....	2
18	18.0	17.3	16.8	16.4	15.6	14.3	13.0	11.4	9.7	7.6	5.1	....	....
19	19.0	18.2	17.7	17.3	16.5	15.1	13.7	12.0	10.2	8.0	5.4	....	....
20	19.9	19.1	18.6	18.2	17.3	15.9	14.3	12.6	10.7	8.4	5.7	....	....
													55
80-FOOT TREES.													
8	8.2	7.8	7.6	7.3	7.0	6.7	6.4	6.0	5.4	4.7	3.7	2.5	1
9	9.2	8.8	8.5	8.2	7.9	7.5	7.1	6.7	6.0	5.2	4.1	2.8	4
10	10.2	9.8	9.5	9.1	8.8	8.3	7.8	7.3	6.6	5.8	4.6	3.1	4
11	11.2	10.8	10.4	10.1	9.7	9.1	8.5	7.9	7.2	6.3	5.1	3.4	5
12	12.2	11.7	11.4	11.0	10.6	9.9	9.2	8.6	7.8	6.8	5.6	3.8	6
13	13.2	12.7	12.3	11.9	11.4	10.7	9.9	9.2	8.4	7.4	6.1	4.2	2
14	14.2	13.6	13.2	12.8	12.2	11.4	10.6	9.9	9.0	8.0	6.6	4.6	2
15	15.1	14.6	14.1	13.7	13.1	12.2	11.3	10.5	9.6	8.5	7.1	5.0	1
16	16.1	15.5	15.0	14.6	13.9	13.0	12.0	11.2	10.2	9.1	7.6	5.4	....
17	17.0	16.4	15.9	15.5	14.8	13.8	12.7	11.8	10.8	9.7	8.1	5.7	....
18	18.0	17.3	16.8	16.4	15.7	14.6	13.4	12.4	11.4	10.2	8.6	6.1	....
19	19.0	18.2	17.7	17.3	16.6	15.3	14.1	13.1	12.0	10.7	9.0	6.4	....
20	19.9	19.1	18.6	18.2	17.4	16.1	14.8	13.7	12.6	11.3	9.5	6.7	....
													25

TABLE 22.—*Average diameter outside bark at different heights above the ground for jack pine trees of different diameters on quality "poor" and quality "good" sites, in Hubbard County, Minn., for trees grown mostly in dense, even-aged stands 18 to 78 years old on quality "poor," and 20 to 45 years old on quality "good" sites.*

[Measurements by H. H. Chapman, 1905.]

SITE QUALITY "POOR."

Diameter breast high.	Height above ground (feet).								Basis.
	1	9	17	25	33	41	49	57	
	Diameter outside bark (inches).								
Inches.									*Trees.*
1	1.7	0.9	0.4	....	....	....	....	....	1
2	2.8	1.8	1.2	....	....	....	....	....	11
3	3.9	2.8	2.1	1.1	....	....	....	....	22
4	5.0	3.7	3.0	2.1	....	....	....	....	30
5	6.2	4.6	3.9	3.1	2.4	....	....	....	55
6	7.3	5.5	4.8	4.0	3.2	....	....	....	43
7	8.4	6.4	5.7	4.9	4.1	2.9	....	....	60
8	9.6	7.4	6.6	5.8	4.9	3.8	....	....	37
9	10.7	8.3	7.4	6.6	5.8	4.7	3.1	....	28
10	11.8	9.3	8.3	7.5	6.6	5.4	3.8	2.2	25
11	12.9	10.3	9.2	8.3	7.3	6.0	4.4	2.7	14
12	13.9	11.2	10.1	9.1	8.0	6.6	5.0	3.2	9
13	14.9	12.2	11.0	10.0	8.7	7.2	5.6	3.7	....
14	15.9	13.1	11.9	10.7	9.4	7.7	6.1	4.2	3
15	16.9	14.1	12.8	11.5	10.0	8.3	6.6	4.6	1
16	18.0	15.0	13.7	12.3	10.7	8.8	7.0	5.0	....
17	19.0	16.0	14.6	13.0	11.3	9.4	7.5	5.4	3
									342
SITE QUALITY "GOOD."									
2	2.7	1.7	....	....	....	....	....	....	2
3	3.9	2.6	2.1	....	....	....	....	....	8
4	5.1	3.6	2.9	2.3	1.4	....	....	....	26
5	6.3	4.6	3.8	3.0	2.0	....	....	....	30
6	7.5	5.5	4.6	3.7	2.6	....	....	....	26
7	8.6	6.4	5.4	4.4	3.2	1.9	....	....	34
8	9.8	7.3	6.2	5.1	3.7	2.1	....	....	18
9	10.9	8.2	7.0	5.8	4.3	2.4	....	....	22
10	12.0	9.0	7.8	6.5	4.8	2.8	....	....	19
11	13.0	9.9	8.6	7.2	5.4	3.3	....	....	7
12	14.2	10.8	9.3	7.8	6.0	3.9	....	....	4
13	15.2	11.7	10.1	8.5	6.6	4.6	....	....	6
14	16.3	12.6	10.9	9.2	7.3	5.3	....	....	3
15	17.3	13.5	11.7	9.8	7.9	6.1	....	....	....
16	18.3	14.4	12.5	10.5	8.6	6.8	....	....	2
									207

ABLE 23.—*Total volume of stemwood in cubic feet of jack pine trees of different diameters and heights in Minnesota.*

[Based on taper curves.]

Diameter breast high.	Total height of trees (feet).							Bark.	Basis.
	20	30	40	50	60	70	80		
	Total volume, including bark (cubic feet).								
Inches.								*Per cent.*	*Trees.*
2	0.3	0.4	0.5	....	....	....	....	22.8	15
3	.6	.8	1.0	1.3	....	....	....	21.3	28
4	1.1	1.4	1.8	2.3	....	....	....	20.0	66
5	1.7	2.1	2.7	3.5	....	....	....	19.0	73
6	2.5	3.1	3.9	5.0	6.1	7.1	....	18.1	93
7	3.4	4.2	5.2	6.8	8.3	9.7	....	17.4	95
8	4.4	5.4	6.7	8.7	10.7	12.5	14.8	16.9	72
9	....	6.9	8.5	10.8	13.3	15.8	18.7	16.4	62
10	....	8.3	10.3	13.4	16.0	19.1	23.0	16.0	64
11	....	....	12.4	15.8	19.4	23.0	27.0	15.6	36
12	....	....	14.5	18.5	23.0	27.0	32.0	15.2	27
13	....	....	16.6	22.0	26.0	31.0	38.0	14.7	10
14	....	....	19.2	25.0	30.0	36.0	43.0	14.2	8
15	....	....	....	28.0	34.0	40.0	49.0	13.6	2
16	....	....	....	31.0	38.0	46.0	55.0	13.0	4
17	....	....	....	35.0	43.0	51.0	61.0	12.3	3
18	....	....	....	38.0	47.0	56.0	66.0	11.5	....
19	....	....	....	....	52.0	62.0	74.0	10.7	....
20	....	....	....	....	56.0	67.0	80.0	9.8	....
									658

ABLE 24.—*Merchantable volume of stemwood in cubic feet of jack pine trees of different diameters and heights in Minnesota.*

[Based on taper curves. Stump height, 1 foot; top diameter outside bark, 3 inches.]

Diameter breast high.	Total height of trees (feet).							Bark.	Basis.
	20	30	40	50	60	70	80		
	Merchantable volume, including bark (cubic feet).								
Inches.								*Per cent.*	*Trees.*
4	0.9	1.1	1.5	2.1	....	....	....	20.0	66
5	1.4	1.8	2.5	3.3	....	....	....	19.0	73
6	2.2	2.7	3.5	4.6	5.8	6.9	....	18.1	93
7	3.0	3.8	4.8	6.3	7.7	9.4	....	17.4	95
8	4.0	4.9	6.1	8.0	10.1	12.0	14.2	16.9	72
9	....	6.2	7.8	10.2	12.5	15.2	18.0	16.4	62
10	....	7.7	9.6	12.3	15.4	18.3	22.0	16.0	64
11	....	....	11.4	14.8	18.2	22.0	26.0	15.6	36
12	....	....	13.5	17.3	22.0	26.0	31.0	15.2	27
13	....	....	15.5	20.0	25.0	30.0	36.0	14.7	10
14	....	....	18.0	23.0	29.0	34.0	41.0	14.2	8
15	....	....	....	26.0	32.0	39.0	47.0	13.6	2
16	....	....	....	29.0	37.0	44.0	52.0	13.0	4
17	....	....	....	33.0	41.0	49.0	59.0	12.3	3
18	....	....	....	36.0	46.0	54.0	65.0	11.5	....
19	....	....	....	....	50.0	59.0	72.0	10.7	....
20	....	....	....	....	55.0	66.0	79.0	9.8	....
									615

TABLE 25.—*Volume in board feet of jack pine trees of different diameters and heights in Minnesota.*

[Scaled by Scribner Decimal C log rule. Stump height, 1 foot: top diameter inside bark, 5.5 inches. Based on taper curves, scaled mostly as 16.3-foot logs, with a few shorter logs where necessary.]

Diameter breast high.	Total height of trees (feet).							Basis.
	20	30	40	50	60	70	80	
	Volume (board feet).							
Inches.								*Trees.*
8	9	10	11	15	23	36	50	72
9	....	15	17	24	34	50	68	62
10	....	20	23	34	46	65	87	64
11	....	....	29	43	59	81	108	36
12	....	....	36	53	73	98	130	27
13	....	....	43	64	88	116	152	10
14	....	....	51	76	104	136	176	8
15	....	....	....	90	121	158	203	2
16	....	....	....	104	139	182	232	4
17	....	....	....	118	158	207	263	3
18	....	....	....	134	178	234	294	....
19	....	....	....	....	198	262	327	....
20	....	....	....	....	220	291	363	....
								288

TABLE 26.—*Volume in board feet of jack pine trees of different diameters, and number of logs per tree, in Minnesota.*

[Scaled by Scribner Decimal C log rule. Stump height, 1 foot; top diameter inside bark, 5.5 inches. Based on taper curves; scaled mostly as 16.3-foot logs, with a few shorter logs where necessary.]

Diameter breast high.	Number of 16-foot logs.							Basis.
	1	1½	2	2½	3	3½	4	
	Volume (board feet).							
Inches.								*Trees.*
8	14	24	39	54	....	....	....	72
9	17	27	42	59	....	....	....	62
10	20	30	46	65	82	....	....	64
11	....	33	51	72	93	....	....	36
12	....	37	57	81	105	132	....	27
13	....	41	64	90	118	147	....	10
14	....	45	73	101	131	163	187	8
15	....	....	83	113	146	181	213	2
16	....	....	94	127	163	201	239	4
17	....	....	106	141	180	223	266	3
18	....	....	121	156	198	245	294	....
19	....	....	....	171	217	269	322	....
20	....	....	....	188	237	293	351	....
								288

TABLE 27.—*Volume in board feet of white pine trees of different diameters and heights.*

[Based on mill cut of lumber from 1,578 trees in southern New Hampshire, 60 per cent being round-edged lumber. Measurements by L. Margolin, 1905.]

Diameter breast high.	Total height of trees (feet).					
	30	40	50	60	70	80
Inches.	*Board feet.*	*Board feet.*	*Board feet.*	*Board feet.*	*Board feet.*	*Board feet.*
5	8	12	15			
6	13	20	23	27	29	
7	18	28	34	39	44	
8	24	36	45	53	62	
9	32	44	56	69	81	93
10	41	53	70	85	103	119
11		63	84	103	126	147
12		73	100	125	151	177
13		84	117	148	180	210
14		95	137	173	210	243
15		105	158	200	241	282
16			181	230	277	323
17			209	261	313	368
18			238	297	352	411
19			270	336	393	460
20			302	379	436	506

This table was used in calculating mill-tally yields in Table 10. It is given for comparison with Table 25 showing board-feet contents of jack pine trees of different diameters and heights scaled by Scribner Decima C log rule.

TABLE 28.—*Number of ties per tree in jack pine trees of different diameters in western Ontario.*

From an article by L. M. Ellis in the Forestry Quarterly, March, 1911. Basis 100 trees. Equivalent in board feet added by the author.

Diameter breast high.	Total height (average).	Age (average).	No. 1, 7″ x 7″ x 8′	No. 2, 6″ x 6″ x 8′	Cull, 5″ x 5″ x 8′	Total.	Equivalent in board feet.
Inches.	*Feet.*	*Years.*					
10	56	48		0.8	1.1	1.9	37
11	61	55	0.3	2.0	1.0	3.3	74
12	66	62	1.2	1.8	.8	3.8	94
13	70	70	2.2	1.5	.8	4.5	119
14	74	80	3.2	1.5	.4	5.1	145
15	77	91	3.8	1.3	.3	5.4	158
16	81	107	4.0	1.2	.2	5.4	160

TABLE 29.—*Stand of trees on jack pine land, Roscommon and Crawford Counties, Mich.*

[Average of 100 acres. Measurements by T. H. Sherrard, 1901.]

Diameter breast high.	Jack pine.	Scarlet oak.	Norway pine.	Aspen.	Red oak.	White pine.	White oak.	Tamarack.	Spruce	White ash.	Total.
Inches.											
1	11.86	2.09	0.29	0.42	0.14	0.20	0.08	0.04	......	0.01	......
2	15.69	2,19	.22	.19	.23	.11.	......	.06	0.04	......	......
3	14.42	1.20	.10	.03	.12	.01	.04	.01	.01	.01	......
4	14.47	.97	.08	.02	.03	.03	.01	.01	......	.01	......
5	12.02	.53	.04	.01	.02	.01	.03	.05	.02	......	......
6	8.26	.40	.03	......	.01	......	.05	......	......	......	......
7	4.68	.26	.01	......	.02	......	.04	......	......	......	......
8	2.62	.15	.04	......	.02	......	.01	.01	......	......	......
9	2.69	.07	.01	......	......	......	......	......	......	......	......
10	1.31	.03	.04	......	.01	.01	......	......	......	......	......
11	.27	.04	.04	......	......	......	......	......	......	......	......
12	.05	......	.01	......	......	......	.01	......	......	......	......
13	.01	......	.02	......	......	......	......	......	......	......	......
14	......	......	.06	......	......	......	......	......	......	......	......
15	......	......	.05	......	......	......	......	......	......	......	......
16	......	......	.05	......	......	......	......	......	......	......	......
17	......	......	.10	......	......	......	......	......	......	......	......
18	......	......	.05	......	......	.01	......	......	......	......	......
19	......	......	.06	......	......	......	......	......	......	......	......
21	......	......	.01	......	......	.01	......	......	......	......	......
23	......	......	......	......	......	.01	......	......	......	......	......
24	......	......	.01	......	......	......	......	......	......	......	......
25	......	......	.01	......	......	......	......	......	......	......	......
Total	88.35	7.93	1.36	.67	.60	1.40	.27	.18	.07	.03	99.86
Per cent	88.48	7.94	1.36	.67	.60	.40	.27	.18	.07	.03	100.00
Average diameter	4.40	3.50	10.30	1.80	3.30	6.10	5.10	3.60	3.20	3.00	......

TABLE 30.—*Stand of trees on jack pine land, site quality*[1] *in western Ontario—Average of 11 acres.*

[From an article by L. M. Ellis in the Forestry Quarterly, March, 1911.]

Diameter breast high.	Jack pine.	White birch.	Aspen.	Black spruce.	Balsam.
	Average number of trees per acre.				
Inches.					
4	1.0	26.2	0.8	13.0	....
5	1.2	24.7	1.7	21.5	0.5
6	1.2	22.5	4.2	19.2	.25
7	6.0	25.0	2.7	15.2	.75
8	12.5	16.7	4.2	9.5	.75
9	17.5	7.0	4.5	6.5	.50
10	12.5	2.5	3.7	2.5	.50
11	12.2	1.7	3.0	2.2	.25
12	11.2	1.2	2.5	1.7	.25
13	11.0	.5	1.7	.02	.25
14	6.0	....	.7	....	.25
15	3.1	....	.02	....	....
16	1.0	....	....	....	....
Total	93.0	128.0	27.0	91.0	4.0
Per cent	27.0	37.0	8.0	27.0	1.0
	Trees 10 inches and over in diameter, breast high.				
Total	57.0	59.0	11.6	6.4	1.50
Per cent	42.0	44.0	8.4	4.6	1.0

Yield of jack pine on these acres about 25 per cent higher than the average for this type in western Ontario.

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[1] Deep, well-drained soil on which jack pine produces its largest returns in sizes suitable for cross ties.

TABLE 31.—*Stand of trees on jack pine land, site quality*[1] *in western Ontario—Average of 10 acres.*

[From an article by L. M. Ellis in the Forestry Quarterly, March, 1911.]

Diameter breast high.	Jack pine.	Black spruce.	Balsam fir.	Larch.	Birch.	Aspen.
	Average number of trees per acre.					
Inches.						
4 and under	8.2	124.4	44.1	0.8	20.8	0.4
5	8.8	41.7	2.2	1.3	4.3	.6
6	16.5	40.4	.4	1.6	8.8	1.8
7	27.4	16.4	.3	2.0	4.8	1.5
8	32.8	14.1	.2	1.4	1.5	1.3
9	16.8	12.3	.2	.6	.4	.5
10	9.6	9.0		.3		.2
11	3.2	3.0		.2		.1
12	1.6			.1		
13	.5					
Total	125.4	235.3	47.4	8.3	40.6	6.4
Per cent	27.0	50.4	11.2	1.5	8.6	1.3
Trees 10 inches and over in diameter breast high.						
Total	14.9	12.0		0.6		0.3
Per cent	54.0	43.0		2.0		1.0

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[1] Includes higher hills and ridges, with scanty soil and lowlands bordering muskegs. In northern Manitoba and northern Ontario the largest part of the interior regions is occupied by this type, on which jack pine rarely reaches merchantable sizes, and never in such bodies as to make commercial exploitation profitable.

TABLE 32.—*Height and yield per acre of managed or normal stands of Scotch pine (Pinus sylvestris) on different qualities of site at different ages.*

[From "Yield Tables for the Scotch Pine," by Wilhelm Weise, converted into English measure and arranged by William Schlich, 1880. Based on 351 Scotch pine woods in Alsace, Baden, Bavaria, Prussia, and Saxony. Cubic feet reduced to cords by dividing by 90.]

Age.	Average height of stand.					Final yield per acre of wood 3 inches and over in diameter.				
	Quality of site.					Quality of site.				
	I.	II.	III.	IV.	V.	I.	II.	III.	IV.	V.
Years.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*
25	31	25	21	18	15	16.22	5.56	3.78	1.89	1.56
30	38	31	26	22	19	24.56	13.00	9.22	4.89	4.00
35	45	36	30	26	22	34.00	23.78	16.00	9.89	6.78
40	51	41	35	31	25	43.00	31.44	21.89	14.33	10.00
45	58	46	39	34	28	50.00	38.56	26.22	18.78	13.00
50	64	51	43	37	31	56.22	43.78	30.00	22.67	15.89
55	68	55	47	40	33	61.56	48.22	33.44	26.00	18.44
60	72	60	51	42	35	66.89	52.11	36.67	29.00	20.78
65	76	64	54	45	37	71.44	55.44	39.67	31.89	23.00
70	80	67	57	47	39	75.44	58.33	42.44	34.11	24.89

TABLE 33.—*Intermediate returns from thinnings in normal stands of Scotch pine on different qualities of site at different ages.*

[From same publication as Table 32.]

Period of years.	Yield per period of years.					Age of stand in years.	Cumulative intermediate yield.				
	Quality of site.						Quality of site.				
	I.	II.	III.	IV.	V.		I.	II.	III.	IV.	V.
	Cords.	*Cords.*	*Cords.*	*Cords.*	*Cords.*		*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*
20 to 25	1.41	0.08	0.03			25	2.17	0.08	0.03		
25 to 30	2.09	.56	.50	0.19	0.10	30	4.26	.63	.53	0.19	0.10
30 to 35	2.81	1.50	1.34	.52	.24	35	7.07	2.13	1.88	.71	.34
35 to 40	3.28	2.42	1.87	.94	.36	40	10.34	4.56	3.74	1.66	.70
40 to 45	3.49	2.81	2.19	1.16	.52	45	13.83	7.37	5.93	2.81	1.22
45 to 50	3.51	3.01	2.29	1.27	.61	50	17.34	10.38	8.22	4.08	1.83
50 to 55	3.63	3.17	2.33	1.42	.68	55	20.98	13.54	10.56	5.50	2.51
55 to 60	3.47	3.11	2.26	1.42	.63	60	24.44	16.66	12.81	6.92	3.14
60 to 65	3.41	3.03	2.04	1.48	.63	65	27.86	19.69	14.86	8.40	3.78
65 to 70	3.30	2.92	1.99	1.40	.63	70	31.16	22.61	16.84	9.80	4.41

TABLE 34.—*Summary of sample plots, site quality "good."*

[Total area of plots, 42.322 acres; average area, 0.694 acre. Measurements by H. H. Chapman, Hubbard County, Minn., 1905. Plot numbers in parentheses indicate selected plots used in construction of yield table.]

Plot number.	Age.	Total.	Living trees per acre.					Average.		Living trees.		Dead trees, per cent of living volume.	Density of stand.
			Jack pine.		Other species.[1]			Diameter, breast high, 5 inches and over.	Dominant height.	Total basal area.	Total yield per acre.		
			5 to 9 inches.	10 inches and over.	1 to 4 inches.	5 to 9 inches.	10 inches and over.						
	Years.							*Inches.*	*Feet.*	*Square feet.*	*Cubic feet.*[2]		
94	18	1,477	38	......	21	......	......	5.2	27	51	726	0.6	1.0
129	20	2,817	11	......	......	......	......	5.0	31	91	1,347	1.7	1.0
74	22	532	188	......	1	......	......	5.4	33	51	824	.7	.9
(75)	23	847	147	......	20	......	......	5.3	36	56	941	.5	1.0
(78)	23	1,021	128	......	8	......	......	5.6	32	60	911	......	1.0
(31)	29	536	290	......	6	......	......	6.5	37	80	1,457	1.4	.9
67	29	528	270	......	41	1	......	5.9	41	67	1,280	.8	.9
120	29	679	400	3	28	1	......	6.5	47	109	2,403	1.4	1.0
(101)	31	553	268	3	16	4	......	6.4	44	75	1,616	2.4	.95
104	31	573	285	......	26	3	......	6.0	38	74	1,378	1.2	.85
110	31	553	293	1	6	......	......	6.2	41	75	1,421	1.1	.9
(139)	31	675	331	4	10	13	......	6.3	43	94	2,009	2.7	1.0
(121)	32	526	373	2	23	4	......	6.7	50	102	2,523	1.0	.95
(124)	32	581	342	......	7	......	......	6.6	45	94	1,966	2.1	.95
100	33	1,020	276	1	7	......	......	6.0	41	87	1,591	.8	1.0
123	33	675	342	2	11	6	......	6.2	44	92	1,761	1.5	.9
(41)	34	505	406	1	14	3	......	6.5	45	103	2,100	3.0	.95
(113)	34	708	343	7	19	1	......	6.4	57	98	2,075	2.6	1.0
(119)	34	437	311	9	22	6	......	6.9	46	93	1,110	.9	.95
140	34	601	299	7	47	13	1	6.5	43	90	1,805	1.7	.95
26	35	871	368	......	3	......	......	5.7	47	94	1,987	5.3	1.0
30	35	741	375	......	......	......	......	6.1	43	99	1,959	3.1	.95
46	35	657	529	9	20	6	......	6.7	52	144	3,529	5.9	.95
47	35	375	241	49	125	81	6	7.5	54	130	3,335	.1	.85
(54)	35	423	332	30	12	7	......	7.2	52	109	2,680	2.5	.95
(127)	35	524	338	8	4	......	......	7.0	50	101	2,411	2.5	.95
136	35	399	255	17	16	14	1	6.9	49	84	1,951	1.3	.9
(44)	36	750	453	1	13	......	......	6.0	46	109	2,461	7.2	1.0
45	36	611	487	......	35	13	......	6.5	49	126	2,977	3.9	.9
48	36	430	355	11	108	15	......	6.9	55	110	2,899	2.9	.95
51	36	795	556	......	10	3	......	6.1	52	132	3,237	6.2	.9
(52)	36	572	434	4	13	4	1	6.6	52	116	2,855	6.7	.95
(53)	36	559	436	2	1	1	......	6.4	50	107	2,638	4.6	.95
(55)	36	721	428	7	10	2	......	6.1	51	111	2,644	5.5	.95
(56)	37	606	422	2	10	......	......	6.4	50	107	2,690	5.6	.95
138	37	560	300	10	24	5	......	6.7	47	92	2,048	1.5	.95
10	38	261	193	41	2	1	......	7.9	62	83	2,435	14.8	.9
(130)	38	499	377	17	......	......	......	6.7	53	104	2,667	6.1	.9
134	38	427	286	2	153	19	......	6.5	46	84	1,841	1.8	.9
43	39	903	616	......	15	......	......	6.1	50	146	3,653	7.2	1.0
(50)	39	524	473	2	......	4	......	6.6	49	118	2,835	12.1	.95
(135)	39	526	377	23	21	4	1	6.9	51	113	2,805	5.3	.95
59	40	343	221	47	4	5	......	7.9	55	97	2,373	9.1	.85
(131)	40	337	242	46	6	1	1	8.0	63	104	3,212	4.5	.9
128	41	678	552	3	......	......	......	6.3	55	131	3,620	12.3	1.0
2	42	399	326	17	9	14	......	7.0	56	100	2,729	7.3	.9
(133)	42	601	369	13	8	1	......	6.6	57	103	3,010	4.3	.9
40	44	424	317	47	......	......	......	7.4	56	114	3,560	3.1	.85
132	45	414	255	44	10	9	2	7.4	58	100	2,761	2.2	.95
3	46	317	265	25	1	3	......	7.4	61	91	2,725	5.1	.85
70	53	360	328	13	......	......	......	7.1	68	97	3,327	29.7	.9
(106)	53	435	350	30	1	......	......	7.3	69	114	3,902	11.1	.9
(112)	53	491	463	15	......	......	......	6.8	63	125	3,924	12.8	.95
111	54	459	414	16	......	......	......	7.1	60	119	3,472	10.8	.9
115	54	592	492	2	......	......	......	6.4	55	117	3,214	11.3	1.0
(126)	54	615	520	......	......	......	......	6.3	57	122	3,580	15.0	1.0
117	56	480	441	8	......	......	......	6.8	60	116	3,555	13.6	1.0
(122)	56	525	486	4	......	......	......	6.6	61	120	3,680	15.4	.95
(19)	57	237	196	37	3	9	2	8.2	63	91	3,683	23.3	.8
107	59	453	412	10	......	......	......	6.9	61	112	3,408	10.6	.9
(21)	62	345	280	50	1	22	2	7.8	65	119	3,719	20.0	.9

---

[1] Includes Norway and some white pine.

[2] All trees 2 inches and over in diameter breast high. Total volume, including bark.

TABLE 35.—*Summary of sample plots, site quality "poor."*

[Total area of plots, 47.921 acres; average area 0.715 acre. Measurements by H. H. Chapman, Hubbard County, Minn., 1905. Plot numbers in parentheses indicate selected plots used in construction of yield tables.]

Plot number.	Age.	Total.	Living trees per acre.					Average.		Living trees.		Dead trees, per cent of living volume.	Density of stand.
			Jack pine.		Other species.[1]			Diameter, breast high, 5 inches and over.	Dominant height.	Total basal area.	Total yield per acre.		
			5 to 9 inches.	10 inches and over.	1 to 4 inches.	5 to 9 inches.	10 inches and over.						
	Years.							*Inches.*	*Feet.*	*Square feet.*	*Cubic feet.*[2]		
98	24	665	157	......	2	......	......	5.2	31	50	762	......	0.85
68	27	810	167	......	10	2	......	5.3	36	57	975	1.0	.9
(77)	30	717	172	......	8	......	......	5.9	37	57	993	.6	.95
99	30	697	252	......	22	1	......	5.6	38	64	1,139	1.5	.9
103	30	520	186	7	9	2	......	6.5	40	62	1,118	.5	.95
60	31	829	199	......	4	......	......	6.1	39	69	1,287	3.1	.95
76	32	672	272	......	88	......	......	5.7	37	69	1,224	.6	.95
(108)	32	855	114	......	......	......	......	5.2	38	49	881	7.2	.95
11	34	832	153	......	12	......	......	5.6	39	56	1,048	1.9	.95
(38)	34	603	307	......	......	......	......	5.8	41	74	1,288	1.8	.9
(79)	34	1,087	158	......	3	......	......	5.4	36	65	1,095	3.2	1.0
102	34	458	159	1	8	......	......	6.1	38	47	851	1.2	.9
81	35	915	262	1	6	......	......	5.8	42	75	1,451	1.4	.95
34	36	976	216	2	13	......	......	5.7	41	81	1,530	3.7	1.0
42	36	507	282	3	21	18	1	6.4	43	84	1,637	3.6	.85
(27)	37	553	264	9	......	......	......	6.2	47	71	1,461	4.0	.95
80	37	1,162	224	......	......	......	......	5.4	40	81	1,546	10.5	1.0
82	37	1,220	57	......	......	......	......	5.2	33	53	805	3.7	.9
105	37	1,125	261	......	1	......	......	5.5	44	89	1,831	3.8	1.0
20	38	262	244	14	......	3	......	7.5	60	80	2,056	33.6	.75
32	38	613	241	17	12	......	1	6.6	46	80	1,712	2.4	.95
39	38	538	244	15	13	2	......	6.6	53	78	2,055	2.7	.8
49	38	215	174	17	66	54	......	7.4	50	80	1,846	.1	.75
137	38	403	225	23	27	3	......	7.1	48	78	1,769	1.8	.9
4	39	625	238	10	25	......	......	6.4	48	78	1,705	2.1	.9
(37)	39	776	259	......	......	......	......	5.5	37	70	1,251	10.6	.95
24	40	437	310	7	6	4	......	6.7	52	91	2,198	5.3	.9
13	41	800	169	......	10	......	......	5.5	36	63	1,092	4.4	.95
(109)	42	505	275	7	6	3	......	6.4	48	76	1,679	1.4	.9
6	51	268	242	24	20	39	......	7.5	60	96	2,823	21.9	.8
(89)	51	573	415	......	......	......	......	6.1	51	88	2,410	6.3	.9
(14)	52	430	360	......	3	3	......	6.4	53	88	2,301	12.8	.85
(12)	53	258	211	23	3	......	......	7.7	58	77	2,207	12.4	.85
83	53	577	416	......	......	......	......	5.9	50	91	2,066	6.9	.9
85	54	531	312	......	......	......	......	5.9	53	78	1,894	5.6	.8
87	54	424	329	3	......	......	......	6.4	53	81	2,028	9.7	.9
116	54	532	452	4	......	......	......	6.6	54	113	2,859	8.9	1.0
125	54	563	461	2	......	......	......	6.2	53	106	2,667	9.9	.95
63	55	505	383	......	......	......	......	5.9	54	83	2,092	20.7	.85
65	55	397	354	5	2	......	......	6.6	60	89	2,642	16.8	.8
71	55	348	308	22	......	......	......	7.3	56	98	2,733	14.5	.9
72	55	397	327	......	......	......	......	6.2	57	74	2,039	13.5	.8
(88)	55	563	372	3	......	......	......	6.2	54	92	2,434	6.0	.95
(91)	55	694	449	......	......	......	......	5.8	48	99	2,414	6.0	.85
(114)	55	473	389	......	......	......	......	6.3	55	92	2,514	15.1	.9
(118)	55	490	450	8	......	......	......	6.7	61	115	3,345	12.4	.95
15	56	402	271	5	14	3	......	6.7	57	77	2,121	8.8	.8
66	56	548	311	......	......	......	......	5.8	50	76	1,669	15.7	.8
62	57	365	322	......	......	......	......	6.0	50	67	1,680	13.4	.75
84	57	368	259	......	......	......	......	5.8	59	55	1,539	8.1	.9
35	58	276	214	50	3	2	3	8.1	61	98	3,059	8.3	.9
61	58	578	312	......	......	......	......	5.9	55	79	1,954	11.4	.8
(28)	59	223	159	64	......	2	......	8.7	62	93	2,764	46.1	.85
(93)	59	537	427	......	......	......	......	6.3	52	101	2,562	13.8	.85
9	60	301	250	11	......	......	......	6.8	57	70	1,867	29.4	.85
86	62	504	386	......	......	......	......	6.3	57	93	2,488	8.4	.95
8	63	348	276	26	2	2	......	7.2	61	90	2,611	16.8	.9
(29)	63	300	246	37	2	3	......	7.6	62	92	2,743	40.2	.8
25	64	244	163	78	......	......	1	8.8	65	102	3,148	8.4	.9
33	66	351	316	24	......	......	1	7.5	63	105	3,110	16.4	.9
16	68	293	221	30	3	17	......	7.7	61	91	2,595	7.2	.8
17	68	316	263	36	3	3	1	7.5	58	94	2,622	6.9	.9
1	70	211	144	67	......	4	......	8.8	62	90	2,897	3.1	.85
(22)	70	436	368	14	......	3	......	6.9	58	105	2,957	8.9	.9
7	71	249	230	14	67	133	2	7.2	58	112	3,223	14.9	.85
5	75	258	244	10	22	78	1	7.1	60	93	2,697	17.2	.85
23	78	250	240	8	30	50	......	7.5	62	94	2,826	28.9	.8

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[1] Includes Norway and some white pine.

[2] All trees 2 inches and over in diameter breast high. Total volume including bark.

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WM. A. TAYLOR, Chief

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FROST PROTECTION IN LEMON ORCHARDS.

By A. D. SHAMEL, *Physiologist*, L. B. SCOTT, *Pomologist*, and C. S. POMEROY, *Assistant Pomologist, Office of Horticultural and Pomological Investigations.*[1]

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CLIMATIC CONDITIONS IN THE CORONA DISTRICT.

ON DECEMBER 25 and 28, 1912, and during January 5, 6, 7, 8, 11, 12, 15, 22, and 23, 1913, many lemon trees in California were severely injured by low temperatures and the accompanying adverse atmospheric conditions, including violent winds and very low relative humidity. As the writers were then stationed in southern California in connection with the citrus-fruit improvement investigations of the United States Department of Agriculture and were spending considerable time in the lemon district near Corona, it seemed advisable to study the effect of these low temperatures in this particular region.

The maximum and minimum temperatures, the rainfall, and notes upon wind and other climatic conditions for December, 1912, and January and February, 1913, in the immediate region where these studies were made are shown in Table I. These data were gathered in accordance with the rules of the United States Weather Bureau, and the climatological instruments were housed in a shelter, as shown in figure 1. On nights when minimum temperatures of 31° F. or lower were recorded, firing was practiced in all orchards that were provided with heaters.

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[1] The writers are especially indebted to Miss Katharine G. Bonner, of the Office of Horticultural and Pomological Investigations, for the computations and the preparation of the tables in this bulletin.

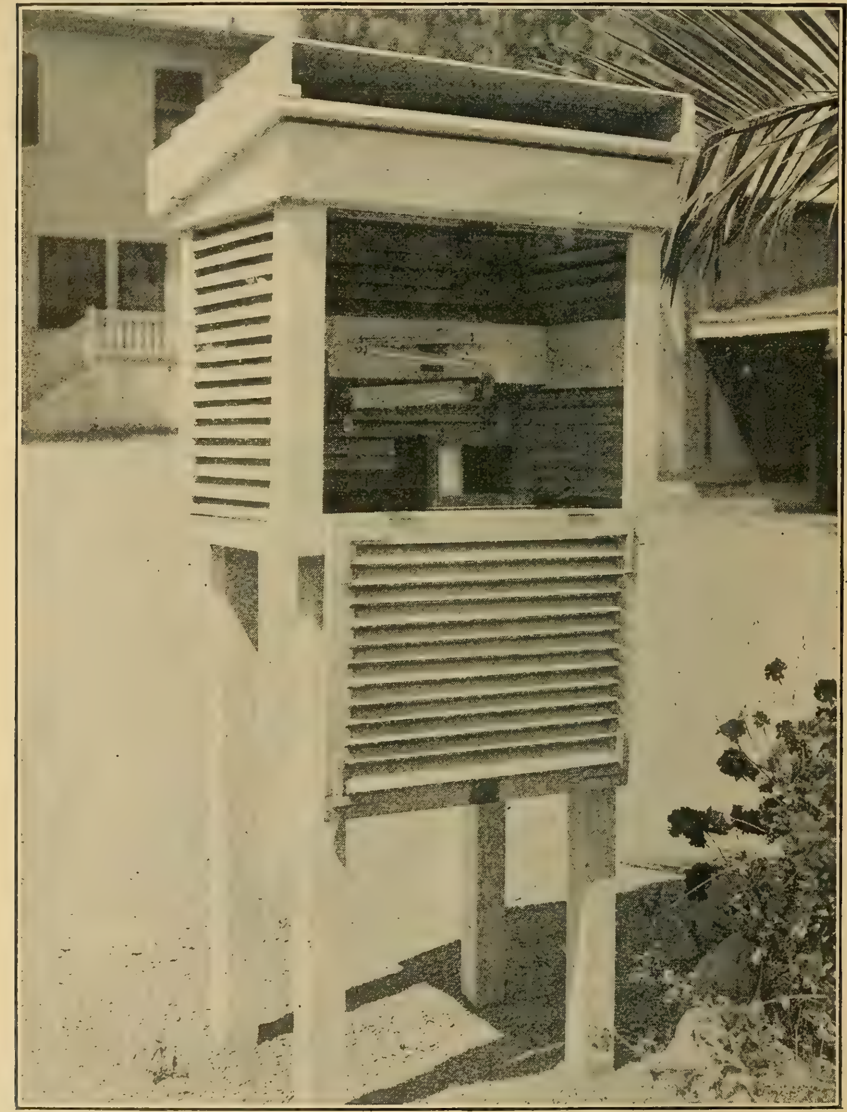


FIG. 1.—Thermometer shelter, showing the arrangement of the maximum and minimum thermometers and the thermograph from which the data presented in Table I were secured. The shelter faces the north, and the instruments are placed about 3 feet from the ground.

The Corona district consists of an area of about 5,000 acres of citrus fruit, in an almost unbroken planting, upon a mesa which slopes to the north and west. The orchards in which the studies discussed in this bulletin were made are located in the center of this area. The altitude of that portion of the mesa where these studies were made is about 1,000 feet. The mesa is protected on the south and east by the Santa Ana Range of mountains, having a general altitude of about 4,000 feet. It faces the Santa Ana River valley to the north and west, and has an open and unobstructed exposure in these directions.

TABLE I.—*Climatological record of a lemon orchard near Corona, Calif., for the months of December, 1912, and January and February, 1913.*[1]

Day of the month.	December, 1912.				January, 1913.				February, 1913.			
	Temperatures (° F.).		Rainfall (inches).	Notes.	Temperatures (° F.).		Rainfall (inches).	Notes.	Temperatures (° F.).		Rainfall (inches).	Notes.
	Maximum.	Minimum.			Maximum.	Minimum.			Maximum.	Minimum.		
1	65	47			74	35			64	39		
2	60	43			79	47			66	41		
3	70	34			83	53			64	34		
4	67	34		(2)	59	32		(3)	64	34		
5	57	38		(3)	55	29		(3)	63	42	Trace.	
6	57	38		(3)	42	19		(4)	70	47	0.38	
7	59	33		(3)	52	25		(3)	60	50	.25	
8	65	41			59	25		(3)	59	47	.65	
9	(5)	36			48	32			69	42		
10	64	34			49	32			69	40		
11	66	32			54	29			64	39		
12	73	41			59	29			71	38		
13	72	39			68	32			78	36		
14	70	32			59	32			73	39		
15	66	38	0.05		58	31	0.88		80	46		
16	58	32			55	42	.33		76	41		
17	75	35			56	39	.14		72	42		
18	78	48			51	34			65	40		
19	75	44			58	40			57	36	.28	
20	68	45		(3)	(5)	(5)	Trace.		57	29		(6)
21	59	30		(3)	64	35			53	39	.32	
22	61	44		(3)	56	27			55	38	.50	
23	68	36			65	30			52	30	.15	
24	66	33			71	44			54	33	1.06	
25	62	31			77	44			54	45	.98	
26	63	42			78	39			54	35	.04	
27	69	41			76	40			58	37	.03	
28	67	31			78	43			63	32		
29	67	32			72	40						
30	66	33			73	38						
31	64	33			78	47						

[1] Records secured by Thos. C. Sias, weather observer for the Corona district.
[2] White frost.
[3] Violent north wind.
[4] Violent north wind; minimum temperature on road alongside orchard at 3 a. m., 17°; temperature did not reach 32° until 11 a. m.
[5] Missing.
[6] No damage, owing to clouds and high humidity.

METHOD OF ORCHARD HEATING.

Many of the lemon orchards in the Corona district were provided with orchard heaters for the protection of the trees and fruits during the low temperatures of December, 1912, and January, 1913. These heaters, for the most part, were oil burners of simple construction. The type of heater in most common use is shown in figure 2. The fuel used was a low grade of distillate. The heaters varied greatly in size, the smaller ones holding from 1 to 3 gallons of fuel each, while the larger ones each had a capacity of 7 to 9 gallons of oil. Some experimental heaters, having a much larger capacity and arranged to provide a more complete combustion of fuel with a consequent small amount of smoke or smudge, were tried during this period, but they were abandoned later, owing to mechanical difficulties and other causes.

Usually one heater for every tree was provided, and in some cases two rows of heaters were arranged on the north and west sides of the orchards. The heaters were usually placed in the center of the square made by four trees, as shown in figure 3, so as to avoid as far as possible injuries to the foliage and fruits from the flames or from close contact with the heaters. They were lighted, as a rule, when the temperature in the orchards dropped to 31° F., although the temperatures at which lighting began depended somewhat upon other conditions than those of temperature and the time of night at which the low temperature was reached. For example, if the temperature dropped to 32° F. before midnight the heaters were usually lighted at this temperature. If the temperature did not drop below freezing until the early morning, as was frequently the case, the heaters were usually lighted at 30° F. In some cases when the temperature did not drop too near the danger point until 5 to 6 a. m. the heaters were not lighted until the thermometer reached 29° or 28° F.

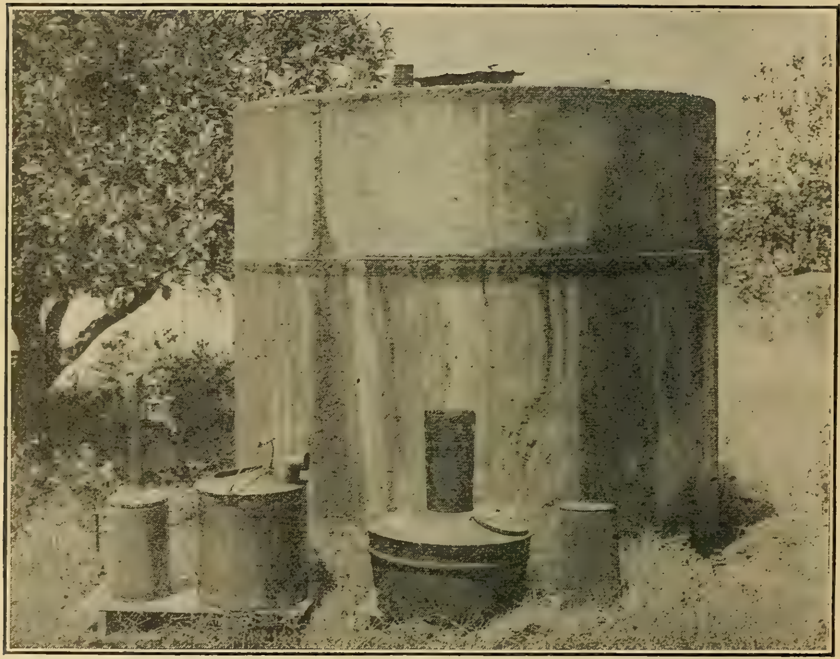


FIG. 2.—The type of heater in most common use in the Corona district. From left to right in the foreground are shown a gasoline torch for lighting the orchard heaters, a can for distributing oil to the heaters, and a style of heater of about 9 gallons' capacity. In the background stands a small oil tank. The oil is drawn off from the tank through a valve at its base, shown at the right.

Adequate provision was made in all the protected orchards in which these studies were conducted for refilling the heaters from storage reservoirs, such as the one shown in figure 4, and for their continuous care during the frosts. One of the methods used for distributing the oil is shown in figure 5. It can be safely said that in the orchards under observation the maximum efficiency of the heaters was obtained during the cold periods.

OBJECTS OF THE INVESTIGATIONS.

The effect of the low temperatures upon the lemon trees in nonheated orchards was very noticeable immediately following the freeze. The trees in nonheated orchards were partially or completely defoliated, as shown in Plates I and II. The trees in heated orchards did not show this condition to any marked extent except in the upper branches, where the leaves were blown off by the violent winds which accompanied the low temperatures, as shown in Plate III. In the nonheated orchards in many instances the bark on the branches and, in some cases, on the trunk of the trees, was split more or less severely. Often it was necessary to cut off these injured branches during the spring months following the low temperatures, in order to aid the trees in recovering from frost injury. In nearly all cases where trees were defoliated it was found desirable to whitewash the trunks and main branches, in order to protect the trees from further injury by exposure to the sun. It was therefore possible, in a general way, to determine the amount of immediate injury to the trees themselves.

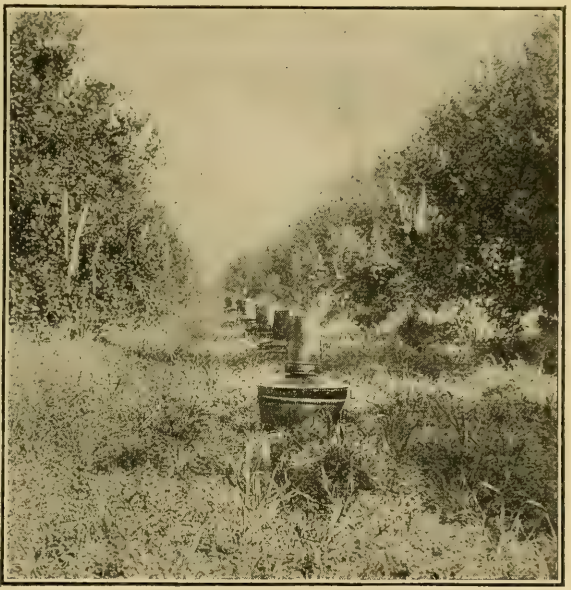


FIG. 3.—Heaters in position for use in a Corona lemon orchard. The heaters are usually set on a small board or other support in order to avoid as far as possible damage from rust due to contact with the soil. Great care must be used in order to prevent leakage from the heaters, as even small quantities of oil in orchard soils have been found to be injurious to the trees. As soon as the cold weather is over, the pots are usually removed from the orchard, emptied, cleaned, coated with hot oil, and stored for the summer.

A number of other factors are of even greater consideration than the immediate injury to the trees. In order to secure definite information concerning these factors, the investigations discussed in this bulletin were undertaken. The objects of these investigations were (1) the determination of the effectiveness of orchard heaters, as measured by the number, commercial quality, and value of the fruits produced by lemon trees in orchards protected by oil heaters and in comparative unprotected orchards, (2) the determination of the length of time it took trees in orchards which were not protected with heaters to return to normal production, (3) the determination of the behavior of lemon trees in heated and nonheated orchards the second year after the freeze, and (4) a comparison of the frost injury in orchards of both Eureka and Lisbon lemon trees, which are the two important varieties grown in California.

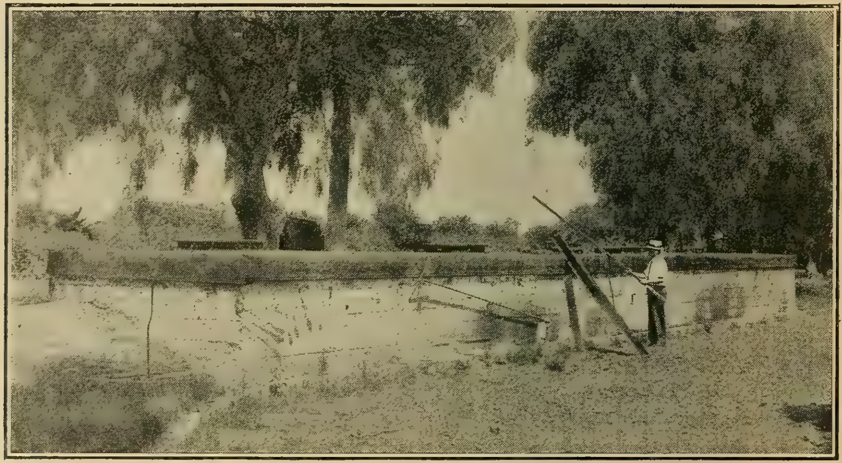
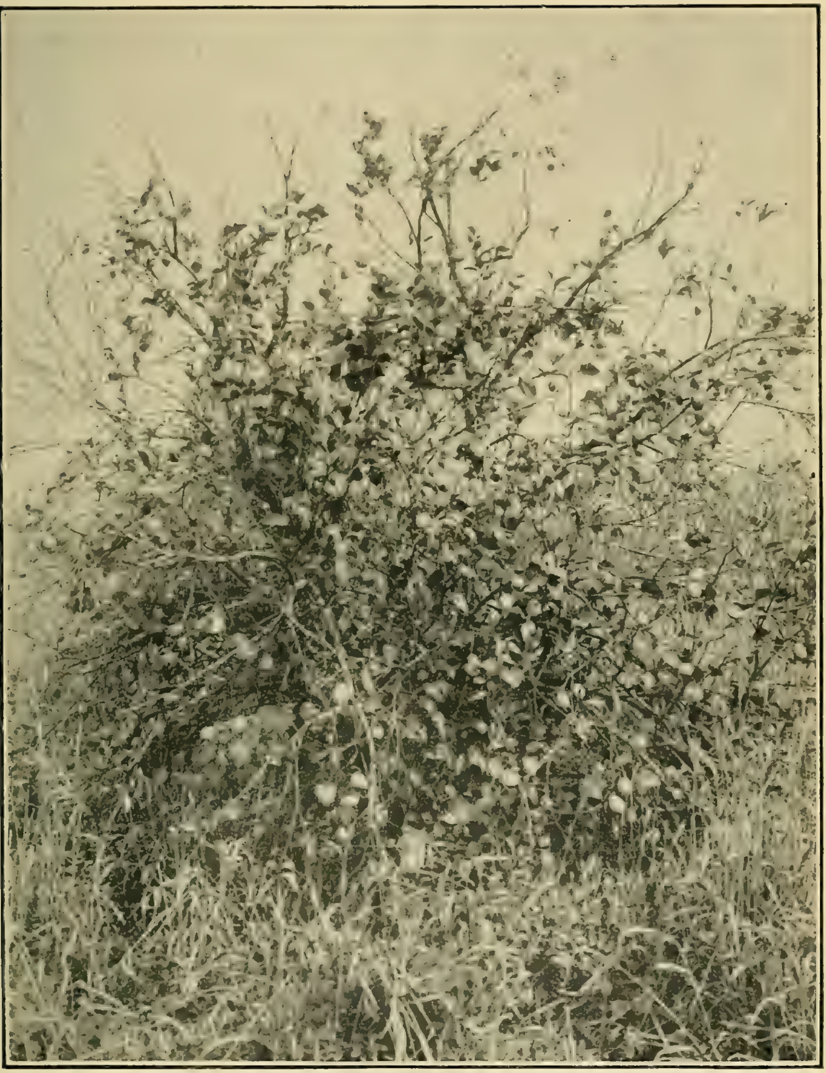


FIG. 4.—Cement reservoir for the storage of oil used in orchard heaters. A large supply of oil is stored in this tank to be used for refilling heaters during periods of low temperature. The reservoir is arranged so that the oil can be carried by gravity through pipe lines to various sections of the orchard, or the oil can be pumped, if necessary, directly into tank wagons for distribution to the heaters.

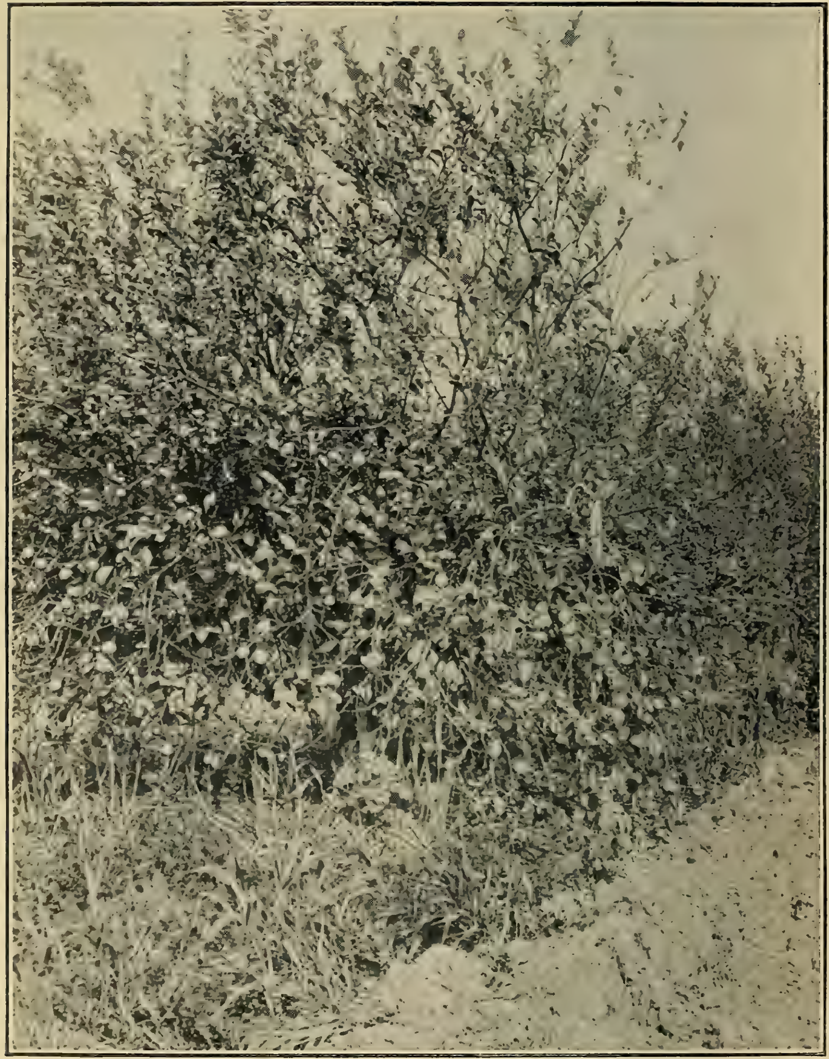
On account of the fact that previous to the freeze no tree records had been kept in the comparative heated and nonheated orchards under observation it is not possible to show the behavior of the trees in these orchards prior to 1913. However, all plats were located in orchards where the conditions were as nearly comparable as possible.

The object of this publication is not to cover the subject of frost protection, but to submit data which shows the actual behavior of trees in protected and unprotected lemon orchards in one district of southern California for the two years following the freeze of January, 1913.



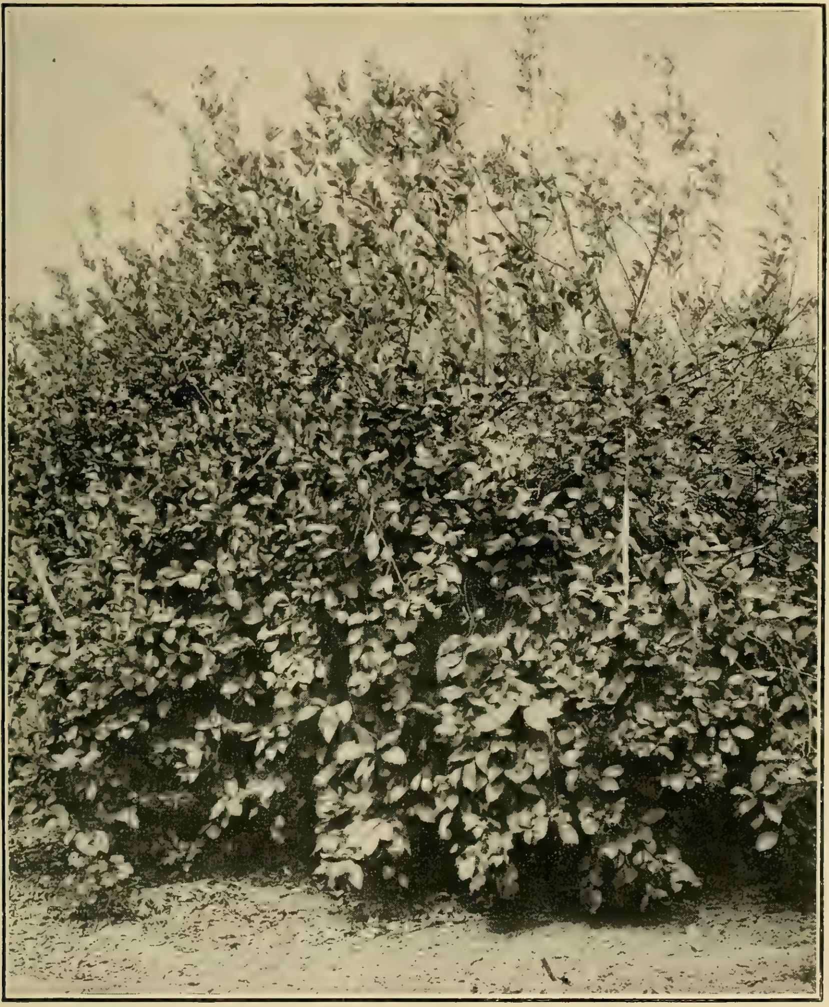
A EUREKA LEMON TREE TYPICAL OF NONHEATED ORCHARDS.

This tree shows excessive defoliation caused by the low temperatures and strong winds during the winter of 1912–13. A comparison with Plate II shows the relatively greater injury done to Eureka than to Lisbon trees in the unprotected orchards. Photographed in January, 1913.



A LISBON LEMON TREE IN PLAT 10, TYPICAL OF NONHEATED ORCHARDS.

Most of the fruits which were not protected by heaters during the low temperatures of 1912–13 were so badly frozen as to render them unmarketable, and the trees were almost defoliated by the low temperatures. Many of the unprotected trees were seriously injured by the splitting of the bark, so that it was found necessary to practice severe pruning in order to cut off the injured limbs and renew the tops. Photographed in January, 1913.



A LISBON LEMON TREE IN PLAT 9, TYPICAL OF PROTECTED ORCHARDS.

While the top of this tree, which was protected by orchard heaters, was partially defoliated by the violent winds, the tree and its fruits were but slightly injured by the low temperatures of 1912–13. Photographed in January, 1913.

PLAN OF THE INVESTIGATIONS.

The investigations discussed in this bulletin were one feature of a general study of the effect of frost injury on citrus fruits conducted by Dr. H. J. Webber, Director of the Citrus Experiment Station of the University of California, at Riverside, his associates, and the writers. A report on certain phases of the studies has been published by Webber and others.[1] Only a brief abstract of the investigations discussed in the following pages appears in the above-mentioned report.

Owing to the fact that frost injuries frequently vary in degree in the same orchard, due to such local conditions as the lay of the land, care was used in the selection of the comparative heated and nonheated plats, so that they were practically identical with respect to the influence of low temperatures and other climatic conditions. A committee, which included Dr. Webber, four prominent citrus growers, and the writers, made the selection of the plats and agreed upon their adaptability for the purpose of this study. In every case the comparative orchards were very near together, usually adjoining groves, and at the same altitude. The trees were about the same age—20 years—so that differences in production could not be attributed to any marked difference in the age of the trees. After a careful survey of the orchards the trees for the comparative plats were selected with a view to insuring fair and comparative conditions.

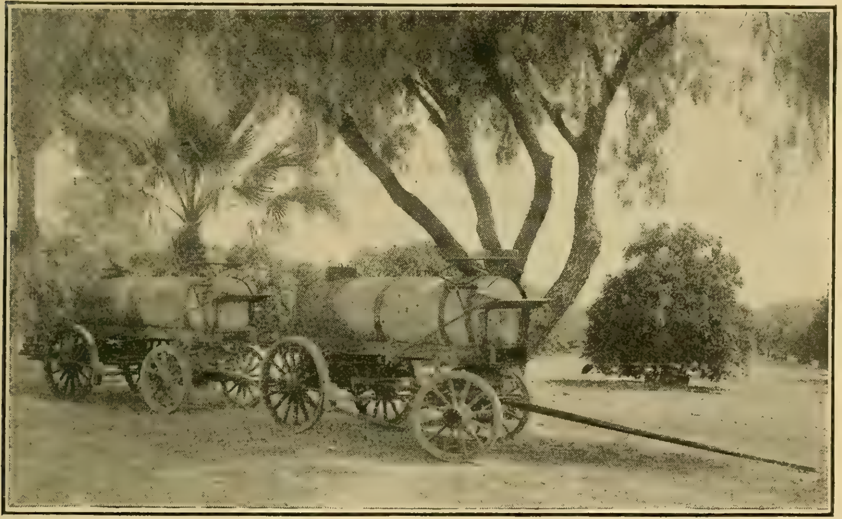


FIG. 5.—Tank wagons used for distributing oil to empty heaters. These provide means for quickly filling the empty heaters during periods of continued low temperature. Some of the orchards are fitted with pipe lines which distribute the oil to different sections.

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[1] Webber, H. J., and others. A study of the effects of freezes on Citrus in California. Cal. Agr. Exp. Sta. Bul. 304, p. 243-321, 22 fig. 1919.

In order to enable the observers to secure individual-tree performance records from as many as 10 plats it was found necessary to arrange the plats in such order that the smallest possible number of trees would give reliable data of the comparative tree and fruit conditions in the heated and nonheated orchards. Each plat included a block 10 trees long by 10 trees wide, or, roughly speaking, an acre of lemon trees. On account of the great amount of work which would be necessary in securing individual-tree performance records from all the trees in the selected plats, it was found necessary to restrict the actual detailed records to not more than 10 trees, and in some cases to 5 trees, in each plat. The trees finally used for this study were located by taking one of the trees at the center of the block and the four trees at the corners. It was thought that by securing the records of these trees and then by multiplying the figures obtained by the factor 20 a fairly accurate line could be obtained on the production of the plat on an acre basis. Where 10 trees were used in securing the records two trees were taken in the center of the block and two on each corner. In these plats the acre figures were secured by multiplying the total production of the 10 trees by the factor 10.

After the performance-record trees were located they were carefully studied from the standpoint of strain characteristics, as it was desirable that only typical trees of the best strain of the Lisbon and Eureka varieties should be used for this study.

TABLE II.—*Description of the plats selected for the study of the effectiveness of orchard heaters for frost protection.*

Plat.	Variety.	Treatment.	Number of trees.	Number of pickings.	Picking period.	Comparative plats.
No. 1	Lisbon	Not heated	5	8	Feb. 14 to Dec. 12, 1913	4
No. 2	do	(1)	5	6	Feb. 15 to Nov. 17, 1913	3
No. 3	Eureka		10	6	do	2, 5, and 7
No. 4	Lisbon	Heated	5	8	Mar. 3 to Dec. 12, 1913	1
No. 5	Eureka	(2)	10	8	Mar. 4 to Dec. 12, 1913	3 and 7
No. 6	Lisbon	Heated	10	19	Mar. 6 to Dec. 8, 1913 Jan. 3 to Dec. 23, 1914	8
No. 7	Eureka	do	10	8	Mar. 7 to Dec. 13, 1913	3 and 5
No. 8	Lisbon	Not heated	10	11	Mar. 10 to Dec. 18, 1913 Jan. 31 to Dec. 30, 1914	6
No. 9	do	Heated	10	8	Mar. 12 to Dec. 12, 1913	10
No. 10	do	Not heated	10	3	Mar. 14 to Dec. 1, 1913	9

[1] Plats 2 and 3 were partially protected by heaters in neighboring orchards.
[2] Inadequately heated; one heater for every four trees.

The position of the plat was adjusted so that the trees finally used were, with one exception, of the same strain in all the comparative plats. The number of the plat, the variety of lemons, a statement of whether the orchards were heated or nonheated, the number of trees in each plat, the number of pickings made from the trees, the periods during which the pickings were made, and the number of plats used for comparison are shown in Table II. A study of this table shows that plats 1, 2, 8, and 10 were located in nonheated Lisbon orchards, while plats 4, 6, and 9 were in heated orchards. Plat 3 was located in a nonheated Eureka orchard, and plats 5 and 7 in heated Eureka orchards. Plats 2 and 3, which are listed as nonheated, were partially protected by heaters in neighboring orchards. Plat 5, which is listed as a heated plat, was inadequately supplied with orchard heaters, as there was only one heater for every four trees. This plat was included for the purpose of comparing inadequate orchard heating with no heating and with adequate heating.

METHOD OF SECURING RECORDS.

The fruit from each individual tree at each picking was assorted into four grades, namely, Green, Tree-Ripe, Frozen, and Cull. The Green grade included all fruits which had either a dark-green or light-green color, and which, from outward appearances, were apparently sound. These fruits were expected after curing to constitute a first grade of valuable commercial lemons. The Tree-Ripe grade included the apparently sound fruits which had a yellow color. These fruits were usually considered to be of some commercial value. It was not necessary to cure them before shipping to the markets. The Frozen grade included all fruits which were seriously injured by the low temperature, as shown by their soft or partially dried-up condition. When there was any question or doubt as to whether the fruit was frozen or not it was cut open, so as to make an accurate determination before classifying. The Cull fruits were those which for some reason aside from frost injuries were unfit for the market. A frequent cause of Culls was decay of various kinds induced by mechanical injury to the fruits. Many of these injuries were brought about by punctures or bruises during the violent winds that accompanied the cold weather in January, 1913.

After the assortment of the fruits from each tree the number and weight of the lemons of each grade were determined and recorded in special field-note forms, as shown in Table III.

As lemons are usually picked to a certain uniform size with the aid of metal picking rings, no attempt was made to size the fruits, as would have been necessary with oranges or grapefruit. If desired, an idea of the relative size of the lemons can be secured by comparing the number with the weights of the fruits.

Inasmuch as the frozen lemons began to dry out soon after the freeze, thus altering their normal weights, the data regarding the comparative sizes of the fruits secured in this way are likely to be somewhat unreliable. For this reason, also, in studying the effect of the freeze upon the production of the trees in the different plats, it seems desirable that most of the conclusions should be based upon the number instead of the weights of the fruits.

TABLE III.—*Field record form used in making individual-tree records in the orchard.*

[This blank provides space for recording data from four trees at one picking. The fruits were sorted into the following grades: Green, Tree-Ripe, Frozen, and Cull, and the number and weight of the fruits in each grade are recorded. The record thus made in the orchard was afterwards transferred to a yearly series form, as shown in Table IV.]

Grove, *Corona Lemon Co.* Date, *Mar. 6, 1913.* Plat, *1.* Variety, *Lisbon.*

Tree.[1]	Green grade.		Tree-Ripe grade.		Frozen grade.		Cull grade.		Total.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
	Lbs oz.		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*	
1-26-17	197 1	684	60 6	291	11 14	64	0 0	0	269 5	1,039
1-26-9	41 14	144	1 10	6	2 11	19	0 0	0	46 3	169
1-26-8	130 12	455	33 9	158	9 9	50	0 0	0	173 14	663
1-32-8	64 4	219	3 4	15	8 14	47	0 0	0	76 6	281

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[1] Each tree in the investigational plat was given an individual-tree number which included the block number, row number, and location of the tree in the row; thus tree 1-26-17 means that that particular tree is in block 1, row 26, and the 17th tree from the end of the row, always numbering from some fixed point.

The data secured for each tree at each monthly picking were transferred to a yearly series record form, as shown in Table IV. The number and weights of the Green, Tree-Ripe, and Frozen fruits for all the record trees in each plat were added at each picking and multiplied by 10 or 20, as determined by the number of record trees, to secure an approximate record of the plat on an acre basis.

TABLE IV.—*Yearly series record form, showing the method of recording data for each tree for an entire year.*

[The monthly records as shown in Table III are here transferred to the yearly form.]

Location, *Corona, Calif.* Variety, *Lisbon.* Grower, *Corona Lemon Co.* Date, *1913.* No. of tree, 1-26-17.

Classification.	Mar. 6.	Apr. 2.	May 14.	June 27.	Aug. 13.	Sept. 15.	Oct. 27.	Dec. 8.	Total.
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	197 1	5 6	11 15	16 13	2 11	0 11	2 11	39 15	277 3
Tree-Ripe grade	60 6	1 11	1 8	3 3	3 2	0 5	1 3	1 10	73 0
Frozen grade	11 14	0 5	0 3	0 0	0 0	0 0	0 7	0 0	12 13
Cull grade	0 0	0 8	0 8	0 4	0 6	0 0	0 9	0 4	2 7
Total	269 5	7 14	14 2	20 4	6 3	1 0	4 14	41 13	365 7
Number of fruits:									
Green grade	684	21	45	65	10	3	11	150	989
Tree-Ripe grade	291	9	5	16	17	2	8	7	355
Frozen grade	64	6	1	0	0	0	3	0	74
Cull grade	0	4	2	2	3	0	4	2	17
Total	1,039	40	53	83	30	5	26	159	1,435

PRESENTATION OF DATA.

In the succeeding tables only the computed figures for the different plats, as shown on an acre basis, are given. It is thought that the presentation of the average number of sound and frozen fruits for each month in the year in all the plats, as expressed in acre terms, will give the reader a comprehensive idea of the behavior of the different orchards under observation. As will be noted in Table II, the first pickings were not all made on the same day. This condition was due to the fact that each plat was of necessity picked in turn, and the careful examination of every fruit for possible frost injury required considerable time. The number of pickings for the plats is not the same in all cases, for the reason that in some of the nonheated plats the great proportion of the fruit on the trees at the time of the freeze was removed at the first picking in 1913, while in some of the heated plats as many as eight pickings were made during the year.

Table V shows the estimated production by grades for an acre of Lisbon lemon trees (plat 1) during February, April, May, June, August, September, October, and December, 1913. These figures are calculated from the actual individual-tree performance records of five selected trees in the plat. This orchard was nonheated during the winter of 1912–13 and was selected for comparison with plat 4, which is in a Lisbon lemon orchard that was heated during that period.

TABLE V.—*Total estimated production by grades from plat 1, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of five Lisbon lemon trees. This plat was not heated during the winter of 1912–13 and was selected for comparison with plat 4 in an orchard of Lisbon lemon trees which was heated during that period. The data from plat 4 are presented in Table VIII.]

Classification.	Date of picking.								Total for year.
	Feb. 14.	Apr. 7.	May 14.	June 24.	Aug. 11.	Sept. 12	Oct. 26.	Dec. 12.	
Number of fruits:									
Green grade	0	13,300	2,500	2,160	540	300	1,100	9,280	29,180
Tree-Ripe grade	0	5,900	320	1,100	640	1,080	600	40	9,680
Total merchantable fruit	0	19,200	2,820	3,260	1,180	1,380	1,700	9,320	38,860
Cull grade	0	1,600	320	740	460	220	800	420	4,560
Frozen grade	183,140	83,360	5,580	1,100	60	340	0	0	273,580
Total	183,140	104,160	8,720	5,100	1,700	1,940	2,500	9,740	317,000
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	0 0	3,506 4	660 0	488 12	125 0	60 0	282 8	2,511 4	7,633 12
Tree-Ripe grade	0 0	1,268 12	73 12	207 8	111 4	145 0	87 8	10 0	1,903 12
Total merchantable fruit	0 0	4,775 0	733 12	696 4	236 4	205 0	370 0	2,521 4	9,537 8
Cull grade	0 0	275 0	60 0	91 4	51 4	28 12	80 0	65 0	651 4
Frozen grade	17,952 8	10,633 12	733 12	101 4	12 8	46 4	0 0	0 0	29,480 0
Total	17,952 8	15,683 12	1,527 8	888 12	300 0	280 0	450 0	2,586 4	39,668 12

A study of the figures shown in Table V shows that at the first picking, on February 14, immediately following the freeze, all of the fruits were frozen. In April the estimated number of sound fruits was 19,200, as compared with 83,360 frozen fruits. In May there were 2,820 sound lemons and 5,580 frozen ones. In June there were 3,260 merchantable fruits, while the frozen fruits had dropped to 1,100. In succeeding pickings the relative proportion of sound fruits to frozen ones is more marked, with a gradual increase in the good fruits, until the December picking, when a total of 9,320 merchantable lemons is recorded, as compared with no frozen ones.

Table VI shows the estimated production by grades for an acre of Lisbon lemon trees (plat 2) during the calendar year 1913. These figures are calculated from the actual individual-tree performance records of five selected trees in the plat. This orchard was not heated during the winter of 1912–13, but was partially protected by heaters in neighboring orchards. It was selected for comparison with plat 3 in an orchard of Eureka lemon trees which was not heated during that period.

TABLE VI.—*Total estimated production by grades from plat 2, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of five Lisbon lemon trees. This plat was not heated during the winter of 1912–13 and was selected for comparison with plat 3 in an orchard of Eureka lemon trees which was not heated during that period. Plat 2 was partially protected by heaters in neighboring orchards. The data from plat 3 are presented in Table VII.]

Classification.	Date of picking.						Total for year.
	Feb. 15.	Apr. 4.	May 27.	June 24.	Aug. 20.	Nov. 17.	
Number of fruits:							
Green grade	16,700	33,160	15,700	6,880	10,480	3,480	86,400
Tree-Ripe grade	120	3,340	4,400	2,560	6,080	1,860	18,360
Total merchantable fruit	16,820	36,500	20,100	9,440	16,560	5,340	104,760
Cull grade	0	780	1,660	1,300	680	2,220	6,640
Frozen grade	54,220	72,640	7,360	1,260	2,180	2,360	140,020
Total	71,040	109,920	29,120	12,000	19,420	9,920	251,420
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	4,235 0	8,621 4	4,081 4	1,742 8	2,251 4	961 4	21,892 8
Tree-Ripe grade	28 12	648 12	873 12	512 8	1,038 12	328 12	3,431 4
Total merchantable fruit	4,263 12	9,270 0	4,955 0	2,255 0	3,290 0	1,290 0	25,323 12
Cull grade	0 0	108 12	240 0	143 12	93 12	333 12	920 0
Frozen grade	5,551 4	10,413 12	1,172 8	196 4	307 8	337 8	17,978 12
Total	9,815 0	19,792 8	6,367 8	2,595 0	3,691 4	1,961 4	44,222 8

A study of the figures in Table VI shows that a large percentage of the fruit in the February and April pickings was frozen. The small number of merchantable fruits recorded at the different pickings throughout the year in this plat is due to the fact that the trees were somewhat protected. This plat, like plat 1, had about returned to normal production at the close of the year.

In Tables VII to XIV, inclusive, the estimated production is shown by grades for plats 3 to 10, inclusive, as described in Table II.

TABLE VII.—*Total estimated production by grades from plat 3, an acre of Eureka lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Eureka lemon trees. This plat was not heated during the winter of 1912-13 and was selected for comparison with plat 2 in an orchard of Lisbon lemon trees which was not heated during that same period and with plats 5 and 7 in orchards of Eureka lemon trees which were heated during that same period. Plat 3 was partially protected by heaters in neighboring orchards. The data from plat 2 are presented in Table VI, from plat 5 in Table IX, and from plat 7 in Table XI.]

Classification.	Date of picking.						Total for year.
	Feb. 15.	Apr. 5.	May 27.	June 21.	Aug. 20.	Nov. 17.	
Number of fruits:							
Green grade	10,330	6,630	1,620	390	1,330	4,750	25,050
Tree-Ripe grade	400	3,070	890	150	520	2,160	7,190
Total merchantable fruit	10,730	9,700	2,510	540	1,850	6,910	32,240
Cull grade	0	260	540	30	200	2,590	3,620
Frozen grade	99,510	29,880	2,190	630	1,550	2,620	136,380
Total	110,240	39,840	5,240	1,200	3,600	12,120	172,240
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	2,519 6	1,769 6	431 14	106 4	301 4	1,331 14	6,460 0
Tree-Ripe grade	91 4	682 8	200 10	29 6	85 10	376 4	1,465 10
Total merchantable fruit	2,610 10	2,451 14	632 8	135 10	386 14	1,708 2	7,925 10
Cull grade	0 0	41 14	115 0	5 10	22 8	293 12	478 12
Frozen grade	6,156 14	4,565 10	318 2	76 4	196 4	290 0	11,603 2
Total	8,767 8	7,059 6	1,065 10	217 8	605 10	2,291 14	20,007 8

TABLE VIII.—*Total estimated production by grades from plat 4, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of five Lisbon lemon trees. This plat was heated during the winter of 1912–13 and was selected for comparison with plat 1 in an orchard of Lisbon lemon trees, which was not heated during that period. The data from plat 1 are presented in Table V.]

Classification.	Date of picking.								Total for year.
	Mar. 3.	Apr. 1.	May 19.	June 23.	Aug. 11.	Sept. 12.	Oct. 26.	Dec. 12.	
Number of fruits:									
Green grade	52,620	9,420	17,980	8,300	2,740	1,080	1,520	11,360	105,020
Tree-Ripe grade	39,840	3,020	4,840	3,160	4,420	2,340	700	80	58,400
Total merchantable fruit	92,460	12,440	22,820	11,460	7,160	3,420	2,220	11,440	163,420
Cull grade	0	1,260	2,600	320	580	160	580	0	5,500
Frozen grade	28,960	1,980	1,320	280	40	40	0	0	32,620
Total	121,420	15,680	26,740	12,060	7,780	3,620	2,800	11,440	201,540
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	13,132 8	2,277 8	2,543 12	2,148 12	681 4	227 8	400 0	3,051 4	24,462 8
Tree-Ripe grade	7,848 12	542 8	982 8	666 4	863 12	373 12	102 8	20 0	11,400 0
Total merchantable fruit	20,981 4	2,820 0	3,526 4	2,815 0	1,545 0	601 4	502 8	3,071 4	35,862 8
Cull grade	0 0	143 12	361 4	47 8	70 0	18 12	50 0	0 0	691 4
Frozen grade	4,045 0	217 8	223 12	53 12	6 4	6 4	0 0	0 0	4,552 8
Total	25,026 4	3,181 4	4,111 4	2,916 4	1,621 4	626 4	552 8	3,071 4	41,106 4

TABLE IX.—*Total estimated production by grades from plat 5, an acre of Eureka lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Eureka trees. This plat was inadequately heated during the winter of 1912–13 and was selected for comparison with plat 3 in an orchard of Eureka lemon trees which was not heated and with plat 7 in an orchard of Eureka lemon trees which was adequately heated during that same period. The data from plat 7 are presented in Table XI and from plat 3 in Table VII.]

Classification.	Date of picking.								Total for year.
	Mar. 4.	Apr. 2.	May 20.	June 27.	Aug. 12.	Sept. 13.	Oct. 26.	Dec. 12.	
Number of fruits:									
Green grade	18,420	2,430	3,580	2,170	770	310	520	3,180	31,380
Tree-Ripe grade	31,420	4,250	2,560	2,810	1,260	710	2,300	110	45,420
Total merchantable fruit	49,840	6,680	6,140	4,980	2,030	1,020	2,820	3,290	76,800
Cull grade	0	1,070	2,580	310	520	140	2,360	160	7,140
Frozen grade	19,610	1,610	470	60	0	60	0	0	21,810
Total	69,450	9,360	9,190	5,350	2,550	1,220	5,180	3,450	105,750
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	4,856 4	570 10	898 12	496 14	185 0	65 10	119 6	828 12	8,021 4
Tree-Ripe grade	6,059 6	744 6	496 14	526 14	233 12	109 6	318 2	25 0	8,513 12
Total merchantable fruit	10,915 10	1,315 0	1,395 10	1,023 12	418 12	175 0	437 8	853 12	16,535 0
Cull grade	0 0	118 12	322 8	35 0	65 10	15 0	151 4	13 12	721 14
Frozen grade	2,565 10	187 8	74 6	6 14	0 0	6 14	0 0	0 0	2,841 4
Total	13,481 4	1,621 4	1,792 8	1,065 10	484 6	196 14	588 12	867 8	20,098 2

TABLE X.—*Total estimated production by grades from plat 6, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Lisbon lemon trees. This plat was heated during the winter of 1912–13 and was selected for comparison with plat 8 in an orchard of Lisbon lemon trees which was not heated during that period. The data from plat 8 are presented in Table XII.]

Classification.	Date of picking.								Total for year.
	Mar. 6.	Apr. 2.	May 14.	June 27.	Aug. 13.	Sept. 15.	Oct. 27.	Dec. 8.	
Number of fruits:									
Green grade	30,030	3,810	2,070	5,390	3,920	1,240	2,430	7,900	56,790
Tree-Ripe grade	10,270	390	200	740	540	950	2,320	2,610	18,020
Total merchantable fruit	40,300	4,200	2,270	6,130	4,460	2,190	4,750	10,510	64,810
Cull grade	0	430	220	200	550	510	700	610	3,220
Frozen grade	4,900	860	140	0	0	580	2,380	240	9,100
Total	45,200	5,490	2,630	6,330	5,010	3,280	7,830	11,360	87,130
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	8,516 4	1,024 6	581 4	1,475 0	986 4	288 2	591 14	2,111 14	15,575 0
Tree-Ripe grade	2,155 10	80 10	51 4	151 14	105 10	150 0	392 8	478 12	3,566 4
Total merchantable fruit	10,671 14	1,105 0	632 8	1,626 14	1,091 14	438 2	984 6	2,590 10	19,141 4
Cull grade	0 0	66 14	31 4	24 6	86 14	60 0	86 4	74 6	430 0
Frozen grade	831 4	98 2	26 4	0 0	0 0	60 10	283 2	33 12	1,333 2
Total	11,503 2	1,270 0	690 0	1,651 4	1,178 12	558 12	1,353 12	2,698 12	20,904 6

TABLE XI.—*Total estimated production by grades from plat 7, an acre of Eureka lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Eureka lemon trees. This plat was heated during the winter of 1912–13 and was selected for comparison with plat 5 in an orchard of Eureka lemon trees which was inadequately heated during the winter of 1912–13 and with plat 3 in an orchard of Eureka lemon trees which was not heated during that same period. The data from plat 5 are presented in Table IX and from plat 3 in Table VII.]

Classification.	Date of picking.								Total for year.
	Mar. 7.	Apr. 3.	May 21.	June 24.	Aug. 11.	Sept. 12.	Oct. 26.	Dec. 12.	
Number of fruits:									
Green grade	42,480	3,970	3,780	3,490	2,110	1,260	2,150	3,020	62,260
Tree-Ripe grade	48,540	3,800	2,250	3,270	3,650	2,620	4,870	1,320	70,320
Total merchantable fruit	91,020	7,770	6,030	6,760	5,760	3,880	7,020	4,340	132,580
Cull grade	0	1,080	2,580	430	650	300	4,480	600	10,120
Frozen grade	6,020	0	10	0	0	20	0	0	6,050
Total	97,040	8,850	8,620	7,190	6,410	4,200	11,500	4,940	148,750
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	11,528 12	995 0	990 0	919 6	500 0	263 2	515 10	820 10	16,532 8
Tree-Ripe grade	10,170 0	702 8	451 4	677 8	620 0	382 8	746 4	335 10	14,085 10
Total merchantable fruit	21,698 12	1,697 8	1,441 4	1,596 14	1,120 0	645 10	1,261 14	1,156 4	30,618 2
Cull grade	0 0	140 10	372 8	57 8	82 8	35 10	369 6	96 4	1,154 6
Frozen grade	841 4	0 0	1 4	0 0	0 0	2 8	0 0	0 0	845 0
Total	22,540 0	1,838 2	1,815 0	1,654 6	1,202 8	683 12	1,631 4	1,252 8	32,617 8

TABLE XII.—*Total estimated production, by grades, from plat 8, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Lisbon lemon trees. This plat was not heated during the winter of 1912–13 and was selected for comparison with plat 6 in an orchard of Lisbon lemon trees which was heated during that period. The data from plat 6 are presented in Table X.]

Classification.	Date of picking.			Total for year.
	Mar. 10.	Nov. 10.	Dec. 18.	
Number of fruits:				
Green grade	2,130	5,780	16,450	24,360
Tree-Ripe grade	1,570	30	70	1,670
Total merchantable fruit	3,700	5,810	16,520	26,030
Cull grade	0	120	170	290
Frozen grade	116,670	0	0	116,670
Total	120,370	5,930	16,690	142,990
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	477 8	1,538 2	4,417 8	6,433 2
Tree-Ripe grade	306 4	5 10	16 14	328 12
Total merchantable fruit	783 12	1,543 12	4,434 6	6,761 14
Cull grade	0 0	13 12	23 12	37 8
Frozen grade	13,685 10	0 0	0 0	13,685 10
Total	14,469 6	1,557 8	4,458 2	20,485 0

TABLE XIII.—*Total estimated production, by grades, from plat 9, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Lisbon lemon trees. This plat was heated during the winter of 1912–13 and was selected for comparison with plat 10 in an orchard of Lisbon lemon trees which was not heated during that period. The data from plat 10 are presented in Table XIV.]

Classification.	Date of picking.								Total for year.
	Mar. 12.	Apr. 3.	May 13.	June 25.	Aug. 12.	Sept. 13.	Oct. 25.	Dec. 12.	
Number of fruits:									
Green grade	64,440	10,270	23,080	19,580	4,900	2,950	220	3,320	128,760
Tree-Ripe grade	80,100	2,310	2,030	21,920	6,400	3,620	1,050	200	117,630
Total merchantable fruit	144,540	12,580	25,110	41,500	11,300	6,570	1,270	3,520	246,390
Cull grade	0	890	2,630	1,870	640	660	2,310	70	9,070
Frozen grade	8,380	60	10	40	0	0	0	0	8,490
Total	152,920	13,530	27,750	43,410	11,940	7,230	3,580	3,590	253,950
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	16,752 8	2,513 2	5,744 6	4,935 0	1,170 0	621 4	57 8	868 12	32,662 8
Tree-Ripe grade	15,280 10	440 0	449 6	4,303 12	1,246 14	575 10	157 8	50 10	22,504 6
Total merchantable fruit	32,033 2	2,953 2	6,193 12	9,238 12	2,416 14	1,196 14	215 0	919 6	55,166 14
Cull grade	0 0	120 10	412 8	222 8	93 2	84 6	120 0	10 0	1,063 2
Frozen grade	924 6	8 12	2 8	5 10	0 0	0 0	0 0	0 0	941 4
Total	32,957 8	3,082 8	6,608 12	9,466 14	2,510 0	1,281 4	335 0	929 6	57,171 4

TABLE XIV.—*Total estimated production, by grades, from plat 10, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Lisbon lemon trees. This plat was not heated during the winter of 1912–13 and was selected for comparison with plat 9 in an orchard of Lisbon lemon trees which was heated during that period. The data from plat 9 are presented in Table XIII.]

Classification.	Date of picking.				Total for year.
	Mar. 12.	May 13.	June 26.	Dec. 1.	
Number of fruits:					
Green grade	3,470	160	450	3,090	7,170
Tree-Ripe grade	4,460	10	1,510	170	6,150
Total merchantable fruit	7,930	170	1,960	3,260	13,320
Cull grade	0	90	120	80	290
Frozen grade	155,230	0	40	0	155,270
Total	163,160	260	2,120	3,340	168,880
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	810 10	35 0	107 8	865 0	1,818 2
Tree-Ripe grade	782 8	1 14	251 14	27 8	1,063 12
Total merchantable fruit	1,593 2	36 14	359 6	892 8	2,881 14
Cull grade	0 0	13 12	11 14	9 6	35 0
Frozen grade	14,475 10	0 0	4 6	0 0	14,480 0
Total	16,068 12	50 10	375 10	901 14	17,396 14

In studying the figures presented in the accompanying tables it will be seen that in all the nonheated plats large numbers of frozen fruits were taken from the trees during the first six months following the freeze. In some of the nonheated plats, very few merchantable fruits were taken from the trees during the same period. On the other hand, in the heated plats the greater proportion of the fruit, even during the period immediately following the freeze, was merchantable, with a relatively small number of frozen lemons.

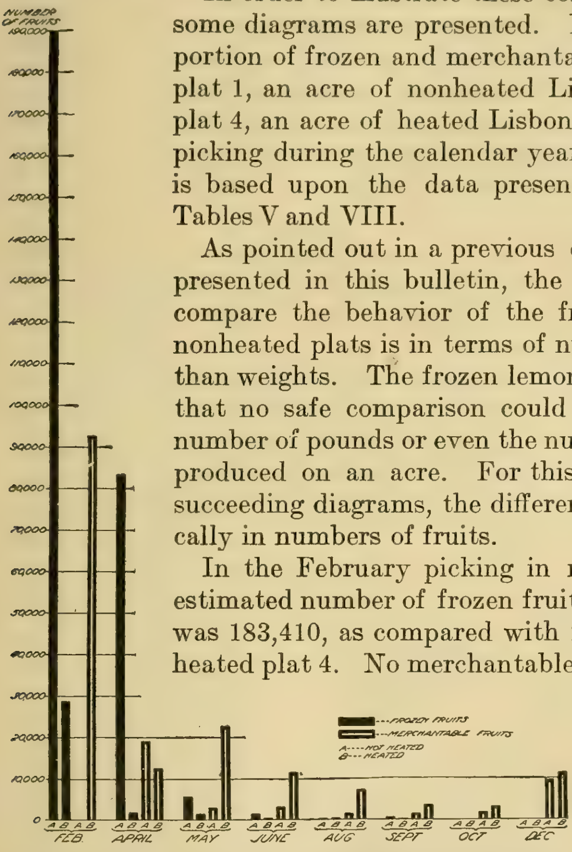

FIG. 6.—Diagram showing the number of frozen and merchantable fruits produced on plat 1, a nonheated acre of Lisbon lemon trees, and plat 4, an acre of heated Lisbon lemon trees. The figures here shown are taken from Tables V and VIII, respectively, which give the estimated production by grades for each month's picking for these plats during the calendar year 1913.

In order to illustrate these comparisons graphically, some diagrams are presented. Figure 6 gives the proportion of frozen and merchantable fruits produced on plat 1, an acre of nonheated Lisbon lemon trees, and plat 4, an acre of heated Lisbon lemon trees, for each picking during the calendar year 1913. This diagram is based upon the data presented for these plats in Tables V and VIII.

As pointed out in a previous discussion of the data presented in this bulletin, the only accurate way to compare the behavior of the fruits in the heated and nonheated plats is in terms of numbers of fruits rather than weights. The frozen lemons dried out so rapidly that no safe comparison could be made by using the number of pounds or even the number of boxes of fruits produced on an acre. For this reason, in this and all succeeding diagrams, the differences are shown graphically in numbers of fruits.

In the February picking in nonheated plat 1, the estimated number of frozen fruits taken from the trees was 183,410, as compared with 28,960 frozen fruits in heated plat 4. No merchantable fruits were taken from the nonheated orchard at that picking, while 92,460 merchantable lemons were picked in the heated orchard during the same period. While many of the frozen fruits which were taken from the trees at that time normally would not have been picked until much later in the season, in order to obtain any records of these fruits it was necessary to pick all which showed signs of having been frozen. All fruits about which there was any question were left until later pickings. This condition applied to all the plats.

In the April picking the estimated number of frozen lemons removed from the nonheated plat was 83,360, as compared with 1,980 from the heated plat. In the nonheated plat 19,200 merchantable fruits were taken from the trees, as compared with 12,440 merchantable fruits in the heated orchard.

In the May picking relatively few frozen fruits were taken from either plat, but only 2,820 merchantable lemons were found in the nonheated orchard, as compared with 22,820 in the heated one.

With the exception of the April picking, in which the first merchantable fruits were taken from the frozen plat, the heated plat produced a greater percentage of merchantable lemons during each picking throughout the calendar year until the last picking in December. At this time the trees in the frozen orchard had about returned to normal production.

A study of the tables and diagrams presented for the other plats shows that practically all the nonheated orchards had returned to normal production by the end of the calendar year.

A similar comparison is shown in figure 7, which portrays graphically the proportion of frozen and merchantable lemons produced on plat 9, an acre of heated Lisbon lemon trees, in comparison with plat 10, an acre of nonheated Lisbon lemon trees. Practically all the frozen fruits in the nonheated orchard were removed from the trees at the first picking in March. The heated orchard had 8,380 frozen fruits during that month, as compared with 144,540 merchantable lemons. During the succeeding months the heated orchard bore a considerable number of sound fruits, while no merchantable lemons were taken from the frozen plat until the December picking, when the trees had about returned to normal production.

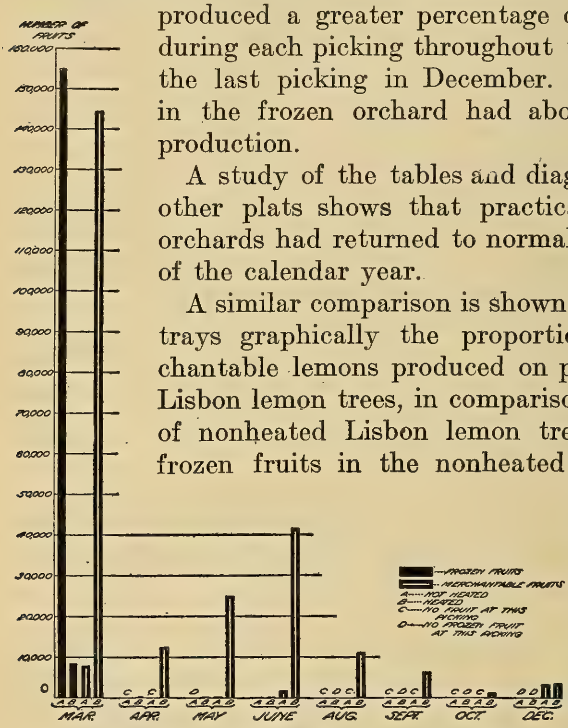

FIG. 7.—Diagram showing the number of frozen and merchantable fruits produced on plat 9, a heated acre of Lisbon lemon trees, and plat 10, a nonheated acre of Lisbon lemon trees. The figures here shown are taken from Tables XIII and XIV, respectively, which give the estimated production by grades for each month's picking for these plats during the calendar year 1913.

Figure 8 shows the number of frozen and merchantable lemons produced on an acre of nonheated Eureka lemon trees (plat 3), as compared with an acre of partially heated (plat 5) and an acre of heated trees (plat 7).

As in figures 6 and 7, the greater proportion of the fruit in the nonheated orchard is found in the frozen column, with a smaller number in the partially heated orchard, and very few frozen fruits in the heated orchard. This diagram shows very clearly the beneficial effect of even a small number of heaters in an orchard, but also presents strikingly the value of efficient heating in orchards, as the number of merchantable fruits produced during the year 1913 in the adequately heated orchard is much greater than that produced in the partially heated one.

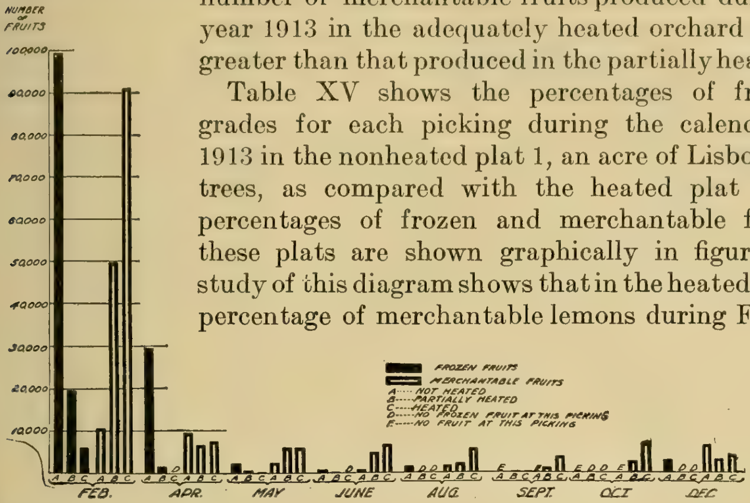

FIG. 8.—Diagram showing the number of frozen and merchantable fruits produced on plat 3, a nonheated acre of Eureka lemon trees, plat 5, a partially heated acre of Eureka lemon trees, and plat 7, an efficiently heated acre of Eureka lemon trees. The figures here shown are taken from Tables VII, IX, and XI, respectively, which give the estimated production by grades for each month's picking for these plats during the calendar year 1913.

Table XV shows the percentages of fruits by grades for each picking during the calendar year 1913 in the nonheated plat 1, an acre of Lisbon lemon trees, as compared with the heated plat 4. The percentages of frozen and merchantable fruits in these plats are shown graphically in figure 9. A study of this diagram shows that in the heated plat the percentage of merchantable lemons during February was 76, while in the nonheated plat the percentage of merchantable fruits was zero. At no time during the calendar year did the curve of merchantable fruits in the heated plat fall below the curve of the same class of fruits in the nonheated one. Correspondingly, the curve of the frozen lemons shows a relatively higher percentage during all the pickings up to October in the nonheated orchard, as compared with a low percentage of this class of fruits in the heated one.

TABLE XV.—*Percentages of fruits by grades produced in the nonheated acre of Lisbon lemon trees, plat 1, as compared with the heated acre, plat 4, during the calendar year 1913.*

[These percentages are computed from the total number of lemons produced by these plats as shown in Tables V and VIII.]

Grade and condition.	Date of picking.							
	Feb. 14.	Apr. 7.	May 14.	June 24.	Aug. 11.	Sept. 12.	Oct. 26.	Dec. 12.
Green grade:								
Not heated	0	12.77	28.67	42.35	31.76	15.46	44.0	95.28
Heated	43.35	60.08	67.24	68.80	35.22	29.83	54.28	99.30
Tree-Ripe grade:								
Not heated	0	5.66	3.67	21.57	37.65	55.67	24.0	.41
Heated	32.81	19.26	18.10	26.20	56.81	64.64	25.0	.70
Merchantable fruit:								
Not heated	0	18.43	32.34	63.92	69.41	71.13	68.0	95.69
Heated	76.16	79.34	85.34	95.0	92.03	94.47	79.28	100
Cull grade:								
Not heated	0	1.54	3.67	14.57	27.06	11.34	32.0	4.31
Heated	0	8.03	9.72	2.65	7.45	4.42	20.72	0
Frozen grade:								
Not heated	100	80.04	63.99	21.57	3.56	17.53	0	0
Heated	23.84	12.63	4.94	2.35	.52	1.11	0	0

Table XVI gives the percentages of fruits by grades for each picking during the calendar year 1913 in the heated plat 6, an acre of Lisbon lemon trees, as compared with the nonheated plat 8. The percentages of frozen and merchantable fruits in these plats are shown graphically in figure 10.

Table XVII gives the percentages of fruits by grades for each picking during the calendar year 1913 in nonheated plat 3, an acre of Eureka lemon trees, as compared with plat 5, inadequately heated, and plat 7, efficiently heated. The percentages of frozen and merchantable fruits in these plats are shown in figure 11.

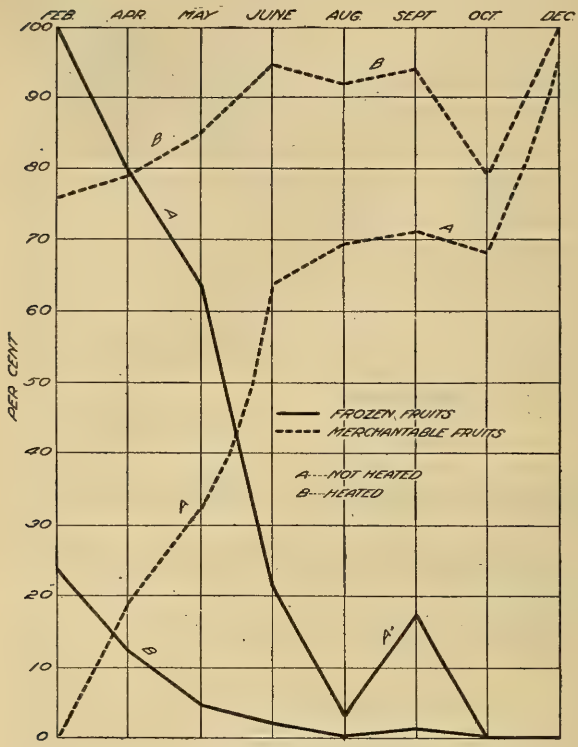

FIG. 9.—Diagram prepared from the figures presented in Table XV, showing the percentages of merchantable and frozen fruits produced on the nonheated acre of Lisbon lemon trees, plat 1, as compared with the heated acre, plat 4, during the calendar year 1913.

TABLE XVI.—*Percentages of fruits by grades produced in the heated acre of Lisbon lemon trees, plat 6, as compared with the nonheated acre, plat 8, during the calendar year 1913.*

[These percentages are computed from the total number of lemons produced by these plats as shown in Tables X and XII.]

Grade and condition.	Date of picking.							
	Mar. 6.	Apr. 2.	May 14.	June 27.	Aug. 13.	Sept. 15.	Oct. 27.	Dec. 8.
Green grade:								
Not heated	1.77	(1)	(1)	(1)	(1)	(1)	97.47	98.56
Heated	66.44	69.40	78.71	85.15	78.24	37.80	31.03	69.54
Tree-Ripe grade:								
Not heated	1.30	(1)	(1)	(1)	(1)	(1)	.51	.41
Heated	22.72	7.10	7.60	11.69	10.78	28.96	29.73	22.97
Merchantable fruit:								
Not heated	3.07	(1)	(1)	(1)	(1)	(1)	97.98	98.97
Heated	89.16	76.50	86.31	96.84	89.02	66.76	60.76	92.51
Cull grade:								
Not heated	0	(1)	(1)	(1)	(1)	(1)	2.02	1.02
Heated	0	7.83	8.36	3.16	10.98	15.55	8.94	5.37
Frozen grade:								
Not heated	96.93	(1)	(1)	(1)	(1)	(1)	0	0
Heated	10.84	15.66	5.32	0	0	17.68	30.40	2.11

[1] Practically all the fruits in the nonheated plat were frozen and were removed from the trees on March 6. No fruits were picked from this plat until October.

Table XVII.—*Percentages of fruits by grades produced in the nonheated acre of Eureka lemon trees, plat 3, as compared with the inadequately heated plat 5, and the efficiently heated plat 7, during the calendar year 1913.*

[These percentages are computed from the total number of lemons produced by these plats, as shown in Tables VII, IX, and XI.]

Grade and condition.	Date of picking.							
	Mar. 4.	Apr. 2.	May 20.	June 24.	Aug. 12.	Sept. 13.	Oct. 26.	Dec. 12.
Green grade:								
Not heated	9.37	16.64	30.92	32.50	36.94	(1)	39.19	(1)
Partially heated	26.52	25.96	38.96	40.56	30.20	25.41	10.03	92.17
Heated	43.78	44.86	43.85	48.54	32.92	30.0	18.69	61.13
Tree-Ripe grade:								
Not heated	.36	7.71	16.98	12.50	14.44	(1)	17.82	(1)
Partially heated	45.24	45.40	27.86	52.52	49.41	58.20	44.44	3.19
Heated	50.02	42.94	26.10	45.48	56.94	62.38	42.35	26.73
Merchantable fruit:								
Not heated	9.73	24.35	47.90	45.0	51.38	(1)	57.01	(1)
Partially heated	71.76	71.36	66.82	93.08	79.61	83.61	54.47	95.36
Heated	93.80	87.80	69.95	94.02	89.86	92.38	61.04	87.86
Cull grade:								
Not heated	0	.65	10.31	2.50	5.56	(1)	21.37	(1)
Partially heated	0	11.43	28.07	5.79	20.39	11.47	45.56	4.64
Heated	0	12.20	29.93	5.98	10.14	7.14	38.96	12.14
Frozen grade:								
Not heated	90.27	75.0	41.79	52.50	43.05	(1)	21.62	(1)
Partially heated	28.24	17.20	5.11	1.12	0	4.92	0	0
Heated	6.20	0	.12	0	0	.48	0	0

[1] No pickings were made from the nonheated plat 3 in September or December.

A study of figure 11 shows that with one exception the curves of merchantable fruit in both the inadequately heated and the efficiently heated plats are considerably higher than the curve of the same class of fruit in the nonheated orchard. The diagram also presents strikingly the differences in percentages of merchantable fruits in the partially heated and efficiently heated orchards. With the exception of the picking in December, the percentages of merchantable fruit in the partially heated orchard are found to be somewhat lower than the same class of fruit in the well-heated one.

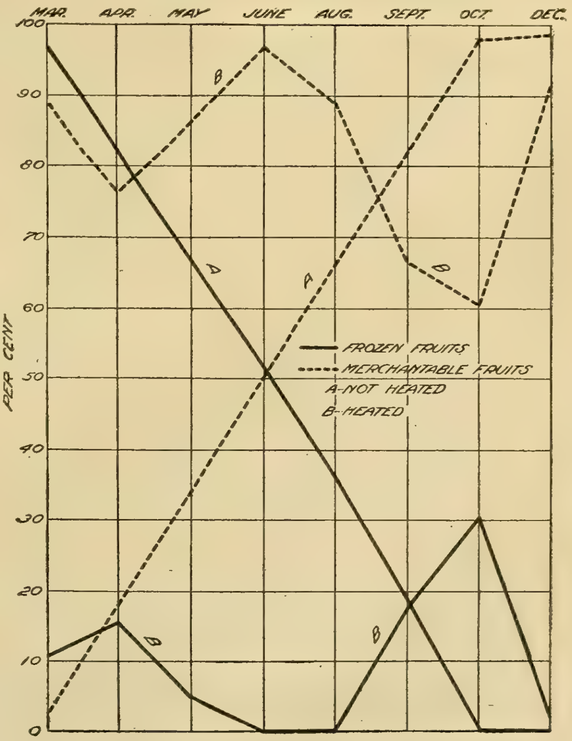

Fig. 10.—Diagram prepared from the figures presented in Table XVI, showing the percentages of merchantable and frozen fruits produced on the heated acre of Lisbon lemon trees, plat 6, as compared with the nonheated acre, plat 8, during the calendar year 1913.

TABLE XVIII.—*Percentages of fruits by grades produced in the nonheated acre of Lisbon lemon trees, plat 10, as compared with the heated plat 9, during the calendar year 1913.*

[These percentages are computed from the total number of lemons produced by these plats, as shown in Tables XIII and XIV.]

Grade and condition.	Date of picking.							
	Mar. 12.	Apr. 3.	May 13.	June 25.	Aug. 12.	Sept. 13.	Oct. 25.	Dec. 12.
Green grade:								
Not heated	2.13	(1)	61.54	21.23	(1)	(1)	(1)	92.51
Heated	42.14	75.91	83.17	45.11	41.04	40.80	6.15	92.48
Tree-Ripe grade:								
Not heated	2.73	(1)	3.85	71.23	(1)	(1)	(1)	5.09
Heated	52.38	17.07	7.32	50.50	53.61	50.07	29.33	5.57
Merchantable fruit:								
Not heated	4.86	(1)	65.39	92.46	(1)	(1)	(1)	97.60
Heated	94.52	92.98	90.49	95.61	94.65	90.87	35.48	98.05
Cull grade:								
Not heated	0	(1)	34.61	5.66	(1)	(1)	(1)	2.40
Heated	0	6.58	9.48	4.31	5.36	9.13	64.53	1.95
Frozen grade:								
Not heated	95.14	(1)	0	1.89	(1)	(1)	(1)	0
Heated	5.48	.44	.04	.09	0	0	0	0

[1] The bulk of the fruits in the nonheated plat were frozen and were removed at the March picking. No fruits were taken from the trees during April, August, and September.

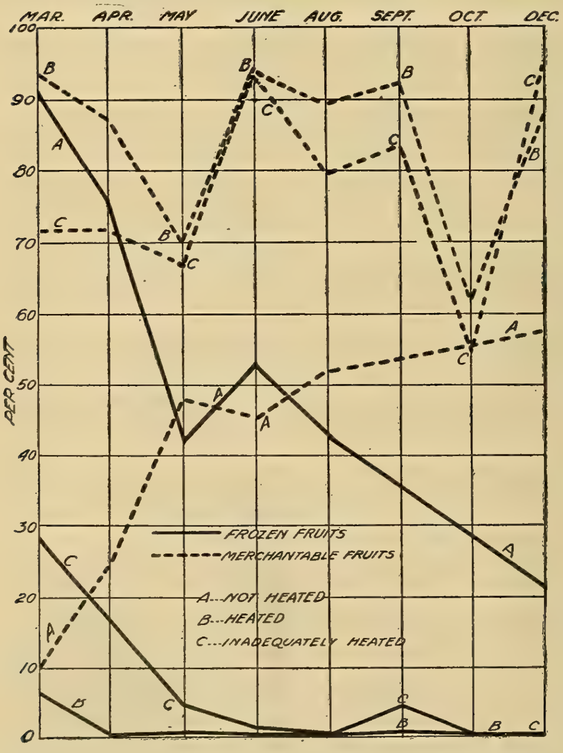

FIG. 11.—Diagram prepared from the figures presented in Table XVII, showing the percentages of merchantable and frozen fruits produced on the nonheated acre of Eureka lemon trees, plat 3, as compared with the inadequately heated acre, plat 5, and the efficiently heated acre, plat 7, during the calendar year 1913.

Table XVIII gives the percentages of fruits by grades for each picking during the calendar year 1913 in the nonheated plat 10, an acre of Lisbon lemon trees, as compared with plat 9, an acre of heated trees. The percentages of frozen and merchantable fruits in these plats are shown in figure 12.

LESSONS TAUGHT BY THE INVESTIGATIONS IN 1913.

The data presented in this bulletin show that in the lemon orchards under investigation in the Corona district of California which were protected with a sufficient number of heaters during the freeze of

1913, a large percentage of merchantable fruits was saved and harvested during the various pickings throughout the year. The studies also show that in orchards which were not heated the number of merchantable fruits was relatively small; that a small proportion of the lemons picked during the first six months was frozen or unmerchantable, and that the trees did not return to normal production for about a year. From the data herewith presented it would appear that in sections where low temperatures are liable to be experienced lemon growers should see that their groves are equipped with some efficient means of orchard heating.

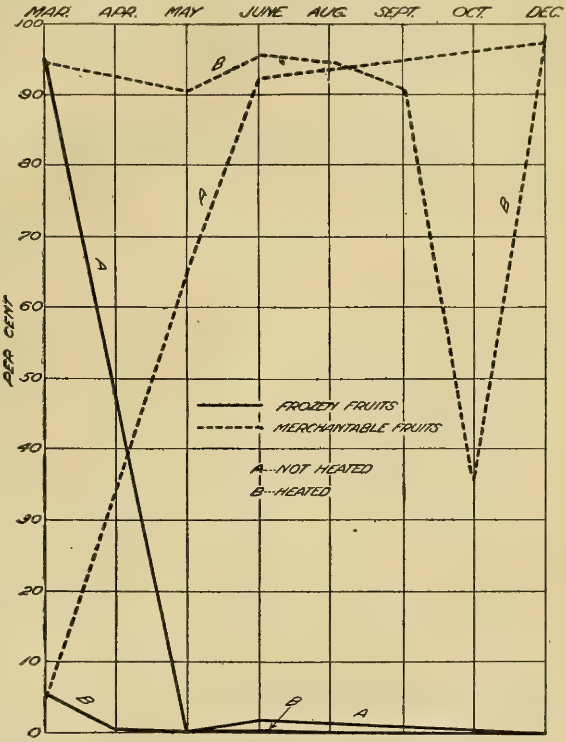

FIG. 12.—Diagram prepared from the figures presented in Table XVIII, showing the percentages of merchantable and frozen fruits produced on the nonheated acre of Lisbon lemon trees, plat 10, as compared with the heated acre, plat 9. during the calendar year 1913.

Table XIX presents a statement of the initial investment for heating equipment per acre and the cost of maintenance and operation for the season of 1912–13. On the particular ranch where these figures apply 186 acres were heated. Some of the heated plats considered in this bulletin were located on this ranch.

As the price received by the grower for merchantable lemons following a freeze is generally considerably higher than that received in normal years, unless he is able to save his crop by orchard heating he is not in a position to reap the benefit of the higher prices which would be obtained during the season of scarcity of sound fruit, and in addition he faces the possibility of losing the greater percentage of his crop. If seasons of low temperature were experienced only at intervals of 10 or 15 years it is possible that growers in especially protected localities might consider that the losing of one year's crop would not be offset by the initial investment for heating equipment and cost of maintenance, which in 1913 was placed in the Corona district at $190.04 per acre. The initial expense of the heating equipment and the cost of maintenance would be much greater at the present time (1920) than in 1913. However, the minimum temperatures experienced in California lemon sections during the last few years show that there is an ever-present danger of frost injury to lemon orchards unless they are safeguarded by an efficient system of heating. From the data presented in this bulletin and from cooperative information secured from lemon growers in different sections, it would appear that the installation of an orchard-heating equipment would be justified not in the saving of one season's crop but because of the frequency with which seasons of low temperatures occur.

TABLE XIX.—*Initial investment for heating equipment and expense per acre for the season of 1912–13 on a ranch of 186 acres at Corona, Calif., on which some of the investigational heated plats were located.*

Itemization.	Per acre.	
	By items.	Total.
Initial investment:		
Heaters	$50.17	$83.12
Oil tank	7.07	
Pipe for oil distribution system	17.49	
Miscellaneous equipment and supplies	7.50	
Labor, installing tank, pipe line, etc	3.89	
Cost of maintenance and operation for the season of 1912–13:		
6 per cent interest on investment	5.17	103.92
25 per cent depreciation on heaters	12.54	
6 per cent depreciation on other equipment	2.16	
Handling, painting, and filling heaters (estimated)	5.00	
Oil consumed	57.96	
Labor in lighting and refilling heaters	21.09	
Grand total (if charged to any one year)		190.04

TABLE XX.—*Total estimated production by grades from plat 6, an acre of Lisbon lemon trees, for each picking during the calendar year 1914.*

[The data in this plat were computed from the individual-tree records of ten Lisbon lemon trees. This plat was heated during the winter of 1913 and was selected for comparison with plat 8 in an orchard of Lisbon lemon trees which was not heated during that period. The data from plat 8 for the calendar year 1914 are shown in Table XXI.]

Classification.	Date of picking.					
	Jan. 3.	Feb. 14.	Mar. 23.	May 4.	June 3.	July 15.
Number of fruits:						
Green grade	30,260	52,120	32,580	22,380	8,640	5,930
Tree-Ripe grade	730	7,210	2,210	5,090	2,360	1,790
Total merchantable fruit	30,990	59,330	34,790	27,470	11,000	7,720
Cull grade	320	1,270	1,660	1,290	340	960
Total	31,310	60,600	36,450	28,760	11,340	8,680
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	7,782 8	14,098 2	8,999 6	5,993 12	2,220 0	1,440 0
Tree-Ripe grade	174 6	1,841 14	536 14	1,206 4	545 0	379 6
Total merchantable fruit	7,956 14	15,940 0	9,536 4	7,200 0	2,765 0	1,819 6
Cull grade	48 12	201 4	267 8	205 10	62 8	158 12
Total	8,005 10	16,141 4	9,803 12	7,405 10	2,827 8	1,978 2

TABLE XX.—*Total estimated production by grades from plat 6, an acre of Lisbon lemon trees, for each picking during the calendar year 1914*—Continued.

Classification.	Date of picking.					Total for year.
	Aug. 18.	Sept. 22.	Oct. 26.	Nov. 23.	Dec. 23.	
Number of fruits:						
Green grade	1,540	1,020	7,660	6,480	10,180	178,790
Tree-Ripe grade	840	1,600	350	490	1,480	24,150
Total merchantable fruit	2,380	2,620	8,010	6,970	11,660	202,940
Cull grade	1,610	450	200	130	240	8,470
Total	3,990	3,070	8,210	7,100	11,900	211,410
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	348 2	244 6	1,991 4	1,770 10	2,823 12	47,711 14
Tree-Ripe grade	154 6	295 10	65 10	96 14	378 2	5,674 6
Total merchantable fruit	502 8	540 0	2,056 14	1,867 8	3,201 14	53,386 4
Cull grade	256 14	62 8	33 2	20 0	35 10	1,352 8
Total	759 6	602 8	2,090 0	1,887 8	3,237 8	54,738 12

THE BEHAVIOR OF HEATED AND NONHEATED PLATS IN 1914.

Although practically all the nonheated plats had returned to normal production by January, 1914, in order to collect data on the behavior of trees in the year following the freeze it was decided to continue the individual-tree records in plat 6, a heated acre of Lisbon lemon trees, and in plat 8, which had not been protected in 1913. The production by grades in these plats during the calendar year 1914 is shown in Tables XX and XXI.

TABLE XXI.—*Total estimated production by grades from plat 8, an acre of Lisbon lemon trees, for each picking during the calendar year 1914.*

[The data in this plat were computed from the individual-tree records of ten Lisbon lemon trees. This plat was not heated during the winter of 1913 and was selected for comparison with plat 6 in an orchard of Lisbon lemon trees which was heated during that period. The data from plat 6 for the calendar year 1914 are shown in Table XX.]

Classification.	Date of picking.								Total for year.
	Jan. 31.	Mar. 14.	Apr. 21	June 3.	July 9.	Aug. 31.	Oct. 31.	Dec. 30.	
Number of fruits:									
Green grade	45,310	40,750	25,140	7,230	7,340	9,400	3,040	13,470	151,680
Tree-Ripe grade	1,490	2,540	11,950	1,090	510	920	2,170	4,380	25,050
Total merchantable fruit	46,800	43,290	37,090	8,320	7,850	10,320	5,210	17,850	176,730
Cull grade	150	1,350	1,210	400	510	760	300	270	4,950
Total	46,950	44,640	38,300	8,720	8,360	11,080	5,510	18,120	181,680
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	12,140 10	11,160 0	6,525 0	1,983 2	1,836 4	2,292 8	803 12	3,601 14	40,343 2
Tree-Ripe grade	358 12	640 10	2,324 6	233 2	97 8	191 4	502 8	1,143 12	5,491 14
Total merchantable fruit	12,499 6	11,800 10	8,849 6	2,216 4	1,933 12	2,483 12	1,306 4	4,745 10	45,835 0
Cull grade	29 6	178 12	197 8	60 0	71 14	139 6	53 12	58 12	789 6
Total	12,528 12	11,979 6	9,046 14	2,276 4	2,005 10	2,623 2	1,360 0	4,804 6	46,624 6

In figure 13 a graphic presentation of the yields of Lisbon lemon trees in the heated plat 6 and the nonheated plat 8 for the two years 1913 and 1914 is given. In 1913 the behavior of the nonheated plat was very similar to other nonheated plats in that the bulk of the fruits was frozen and was removed at the first picking. The plat did not return to normal production until December of that year. In January, 1914, the estimated number of merchantable fruits picked from the nonheated plat was 46,800, as compared with 30,990 on the heated one.

In referring to Tables XX and XXI it will be seen that 11 pickings were made in plat 6 during the calendar year 1914, as compared with 8 pickings in plat 8. This was due to the fact that the two orchards belonged to different companies, and a different system of picking was followed in each orchard. In order to make the data in figure 13 comparable, it was necessary to add the figures obtained in February and March in plat 6 and present them in comparison with the picking in plat 8 in March. The August and September pickings in plat 6 were totaled to make them comparable with the one picking made for the same period in plat 8. A similar addition was made of the September and October pickings in plat 6 to make them comparable with the fruit obtained in plat 8 for the same period. In March the fruits obtained from the heated plat were considerably more than those obtained from the nonheated plat. In May, however, the nonheated plat led, and after that month the two plats alternated throughout the year.

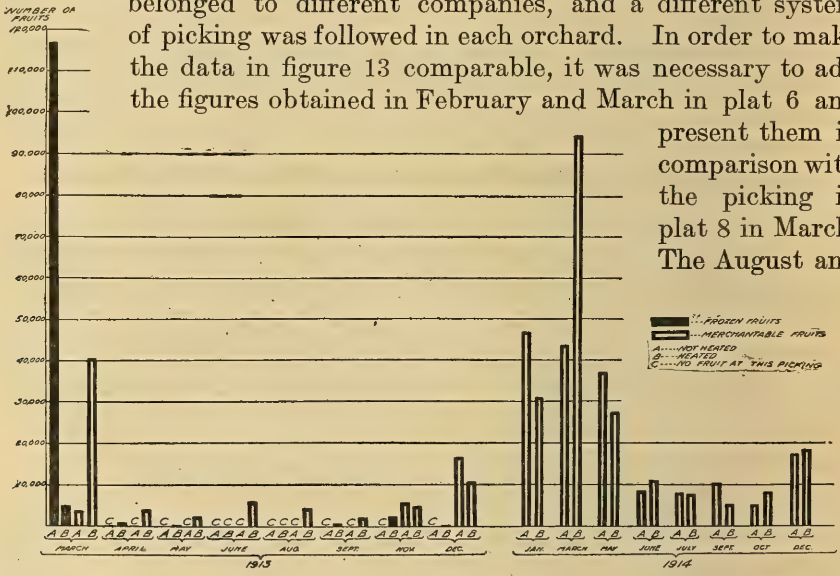

FIG. 13.—Diagram showing the number of frozen and merchantable fruits produced on plat 6, a heated acre of Lisbon lemon trees, and plat 8, a nonheated acre of Lisbon lemon trees, for the calendar years 1913 and 1914. The figures here shown are taken from Tables X, XII, XX, and XXI, respectively, which give the estimated production by grades for each month's picking for these plats during these years.

From the data secured in these two plats it would appear that the nonheated trees had returned to normal production by the beginning of 1914 and that the heating during the cold period in January, 1913, had practically no effect on the second season's crop. It must be borne in mind, however, that the trees in this particular orchard were in a very vigorous and healthy condition at the time of the freeze, and with the exception of lack of heating had always received excellent care, which probably accounts for their rapid return to normal production. If the orchard had not received as good care or had the trees been in a less healthy growing condition, it is possible that they might not have returned to normal production so soon.

In addition to the data covering these two plats, observations made in the other nonheated and heated orchards in 1914 showed that there was very little relative difference in the number of fruits produced the second year by the trees which were heated in 1913 as compared to the nonheated trees.

From these investigations it appears that the main effect of protecting trees during one season of low temperatures is in the saving of the crop for the current year, and that as a rule where the trees are in vigorous condition and receive good cultural treatment they will return to normal production at the end of one year.

COMPARISON OF THE EUREKA AND LISBON VARIETIES.

The two important varieties of lemons grown in California are the Eureka and the Lisbon. In order to secure some definite information as to the behavior of comparative plats in nonheated orchards, two blocks of trees, plats 2 and 3, were located, respectively, in Lisbon and Eureka lemon orchards. Both orchards were operated by the same man, the two plats under observation were only a short distance apart at practically the same altitude, and, as far as could be determined, the conditions were as nearly uniform in each orchard as it was possible to obtain. Both the orchards received some benefit from heaters in neighboring protected groves. A record of the production by grades during the calendar year 1913 for the nonheated Lisbon orchard is given in Table VI and for the nonheated Eureka orchard in Table VII. In figure 14 the number of frozen and merchantable fruits produced on each of these plats for the calendar year 1913 is given.

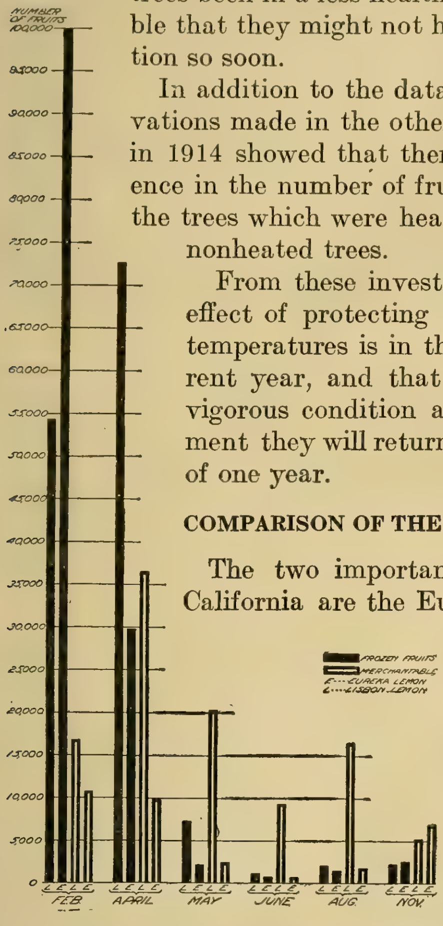

FIG. 14.—Diagram showing the number of frozen and merchantable fruits produced on plat 2, a nonheated acre of Lisbon lemon trees, and plat 3, a nonheated acre of Eureka lemon trees. The figures here shown are taken from Tables VI and VII, which give the estimated production by grades for each month's picking for these plats during the calendar year 1913.

In February the estimated number of frozen fruits picked in the Lisbon plat was 54,220, as compared with 99,510 in the Eureka orchard. On account of the open habit of growth of the Eureka tree a larger number of mature or nearly mature lemons were frozen in this variety than in the Lisbon. In the April picking, however, the estimated number of frozen fruits in the Lisbon plat was 72,640, as compared with 29,880 in the Eureka. The greater number of frozen lemons at this picking in the Lisbon orchard, as compared with the preceding one, was probably caused by the fact that the dense character of growth of the Lisbon trees in this particular orchard hid many of the fruits which should have been removed from the trees at the first picking. After the April picking there was very little difference in the number of frozen fruits produced in each orchard. Both orchards returned to normal production about the last of the year. In the case of the merchantable fruits, however, the Lisbon plat at each picking bore a greater number of sound, merchantable lemons than the Eureka.

The percentages of fruits by the different grades in the Lisbon and Eureka nonheated plats for the different pickings during the current year 1913 are shown in Table XXII.

TABLE XXII.—*Percentages of fruits by grades produced on the nonheated acre of Lisbon lemon trees, plat 2, as compared with the nonheated acre, plat 3, of Eureka lemon trees, during the calendar year 1913.*

[These percentages are computed from the total number of lemons produced by these plats, as shown in Tables VI and VII.]

Grade and variety.	Date of picking.					
	Feb. 15.	Apr. 5.	May 27.	June 24.	Aug. 20.	Nov. 17.
Green grade:						
Eureka	9.37	16.64	30.92	32.50	36.94	39.19
Lisbon	23.51	30.17	53.91	57.33	53.96	35.09
Tree-Ripe grade:						
Eureka	.36	7.71	16.98	12.50	14.44	17.82
Lisbon	.17	3.04	15.11	21.33	31.31	18.75
Merchantable fruit:						
Eureka	9.73	24.35	47.90	45.0	51.38	57.01
Lisbon	23.68	33.21	69.02	78.66	85.27	53.84
Cull grade:						
Eureka	0	.65	10.31	2.50	5.56	21.37
Lisbon	0	.71	5.71	10.83	3.50	22.38
Frozen grade:						
Eureka	90.27	75.0	41.79	52.50	43.05	21.62
Lisbon	76.32	66.08	25.27	10.50	11.23	23.79

A graphic presentation of the percentages of frozen and merchantable fruits in the Eureka and Lisbon nonheated plats is made in figure 15. The percentage of frozen lemons at each picking in the Eureka plat is somewhat higher than the percentage of frozen ones in the Lisbon plat until the last pickings in November, when the percentages are nearly uniform. Correspondingly, the percentage of merchantable fruits at each picking is somewhat higher in the Lisbon block than in the other.

From the data secured in these plats and from observations made in other orchards it appears that the Lisbon variety, probably owing to its dense foliage and more compact habit of growth, was not quite so susceptible to frost injury as the Eureka. These observations apply entirely to groves which are not protected by orchard heaters. In well-protected orchards there were comparatively small numbers of frozen lemons of either the Eureka or Lisbon variety. It therefore appears that, although in unprotected orchards under similar conditions, a greater amount of injury is found in Eureka than in Lisbon orchards, the difference is not sufficiently great to warrant any positive statements concerning the comparative hardiness of the two varieties.

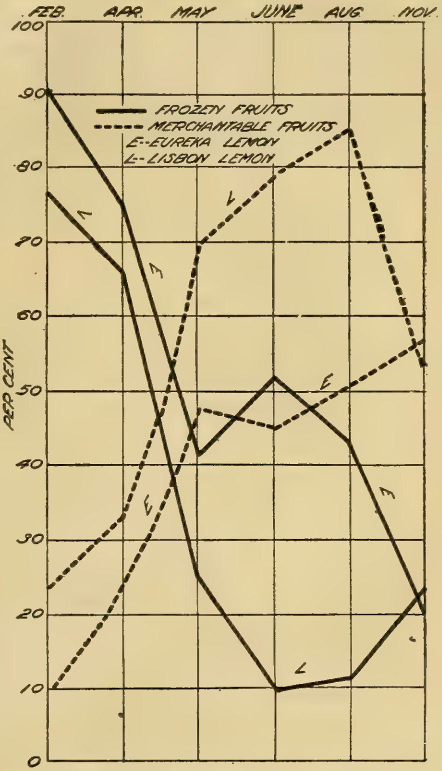

FIG. 15.—Diagram prepared from the figures presented in Table XXII, showing the percentages of merchantable and frozen fruits produced on the nonheated acre of Lisbon lemon trees, plat 2, as compared with the nonheated acre of Eureka lemon trees, plat 3, during the calendar year 1913.

SUMMARY.

Extremely low temperatures during December, 1912, and January, 1913, caused serious damage and loss to unprotected lemon orchards in many sections of southern California.

Detailed records of the proportion of merchantable and frozen fruits produced in five heated and five nonheated acre plats of Eureka and Lisbon lemons during the calendar year 1913 and in two comparative plats during the calendar year 1914 in the Corona, Calif., lemon district are presented in this bulletin.

These data show that in orchards which were protected with an adequate supply of heaters during the cold weather of 1912–13 a large percentage of merchantable fruit was saved and harvested throughout the year.

In orchards which were not heated a large proportion of the lemons picked during the first six months following the freeze were frozen or unmerchantable, and the trees did not return to normal production until a year had elapsed.

Nonheated orchards which had received good care prior to the freeze of 1913 and also during that year had returned to normal production by the beginning of 1914, and the heating during the cold period in 1913 had practically no effect on the second season's crop.

In unprotected orchards, under comparative conditions, a greater amount of injury was found in the Eureka than in the Lisbon variety. The differences were not sufficiently great, however, to warrant the conclusion that there is any considerable difference in the hardiness of the two varieties. Such differences as appeared were entirely due to differences in the habit of growth of the two varieties, the Lisbon having denser foliage.

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BULLETIN No. 822

Joint Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief, and the Bureau of Crop
Estimates, L. M. ESTABROOK Chief.

Washington, D. C. **February 25, 1920**

PEARS: PRODUCTION ESTIMATES AND IMPORTANT COMMERCIAL DISTRICTS AND VARIETIES.

By H. P. GOULD, *Bureau of Plant Industry, and* FRANK ANDREWS, *Bureau of Crop Estimates.*

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RELATIVE IMPORTANCE OF THE PEAR.

Compared with other fruits when the Thirteenth Census was compiled, the pear occupied seventh place in value, being exceeded by the apple, the peach and nectarine (grouped together), the grape, the strawberry, the orange, and the plum and prune (grouped together). It occupied fourth place on the basis of acreage, only the apple, the peach (and nectarine) and the grape exceeding it. The relative importance in acreage and value of different fruits in 1909 is shown graphically in figure 1.

ESTIMATED PRODUCTION OF PEARS.

The estimated production of pears for the years 1909 to 1919, inclusive, is shown in Table I. These estimates include the entire crop, no segregation of the commercial production from the total being made.

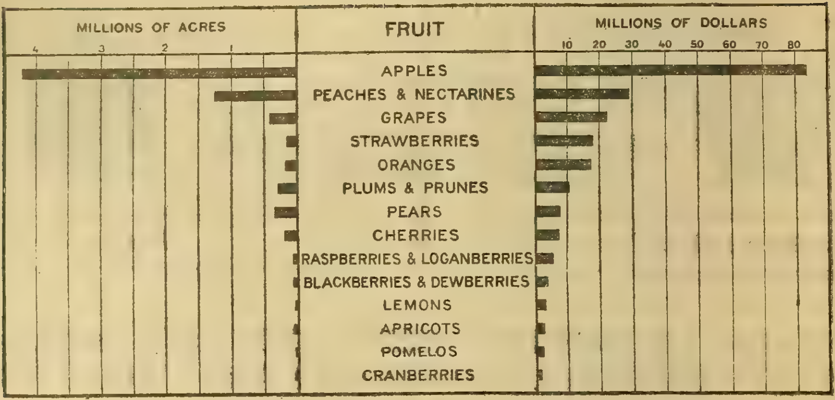

FIG. 1.—Diagram showing the relative importance, acreage, and crop values of the principal fruits of the United States for the year 1909, based on the report of the Thirteenth Census. (From the Yearbook of the Department of Agriculture for 1915.)

TABLE I.—*Estimated production of pears in the United States for the 11-year period from 1909 to 1919, inclusive.*

[Data in bushels, 000 omitted. The figures for 1909 are those of the Thirteenth Census. The figures for other years are interpretations of percentage estimates by the Bureau of Crop Estimates, the census figures being used as the basis.]

Groups and States.	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	a 1919
North Atlantic States:											
Maine	39	35	42	38	32	40	30	36	24	20	44
New Hampshire	24	22	24	19	24	22	18	25	19	15	25
Vermont	21	23	25	20	20	17	17	24	14	13	18
Massachusetts	96	94	114	71	121	98	75	114	71	77	115
Rhode Island	12	12	14	11	16	13	10	14	7	10	12
Connecticut	41	46	46	32	55	43	36	46	29	34	47
New York	1,343	1,530	1,886	1,128	2,016	1,298	1,375	1,675	1,708	1,352	1,530
New Jersey	463	910	970	749	598	876	596	687	590	650	500
Pennsylvania	379	570	646	418	456	608	494	509	448	518	355
Total	2,418	3,242	3,767	2,486	3,338	3,015	2,651	3,130	2,910	2,689	2,646
South Atlantic States:											
Delaware	105	301	262	315	77	210	228	164	294	238	140
Maryland	368	609	455	616	224	500	483	378	525	455	420
Virginia	74	221	122	282	68	234	261	122	194	119	190
West Virginia	30	49	49	76	11	72	63	42	33	33	40
North Carolina	84	164	52	207	58	187	150	75	150	108	84
South Carolina	66	108	52	117	42	109	91	56	100	98	81
Georgia	150	260	111	212	118	208	203	135	140	188	152
Florida	98	153	88	73	58	112	104	54	46	132	70
Total	975	1,865	1,191	1,898	656	1,692	1,583	1,026	1,482	1,371	1,177
East North-Central States:											
Ohio	375	360	736	624	400	544	560	376	334	304	218
Indiana	320	292	585	448	474	422	410	351	410	260	188
Illinois	249	32	499	448	422	422	496	354	456	302	436
Michigan	666	456	829	540	707	840	550	1,007	1,080	704	726
Wisconsin	13	2	18	13	22	22	23	26	......	......	......
Total	1,623	1,142	2,667	2,073	2,025	2,250	2,039	2,114	2,280	1,570	1,568
West North-Central States:											
Iowa	44	1	57	60	102	84	106	63	82	32	58
Missouri	143	67	148	332	184	283	294	164	265	112	280
Nebraska	7	4	10	15	13	14	18	10	14	6	16
Kansas	19	98	70	142	63	109	133	106	140	38	120
Total	213	170	285	549	362	490	551	343	501	188	474

a Subject to revision.

TABLE I.—*Estimated production of pears in the United States, etc.*—Continued.

Groups and States.	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
South-Central States:											
Kentucky	252	180	160	336	160	308	264	160	204	140	128
Tennessee	84	126	32	196	79	152	195	59	75	112	72
Alabama	100	138	48	172	90	132	168	90	80	152	114
Mississippi	101	140	40	154	106	142	160	50	30	136	95
Louisiana	36	32	24	52	48	52	55	48	52	52	50
Texas	111	224	147	296	187	266	301	322	280	246	385
Oklahoma	7	28	33	54	23	28	68	11	45	38	70
Arkansas	38	46	47	113	55	98	135	68	102	64	98
Total	729	914	531	1,373	748	1,178	1,346	808	868	940	1,012
Far Western States:											
Montana	8	......	11	12	10	12	12	6	11	6	11
Colorado	133	121	160	193	130	206	99	99	320	194	180
New Mexico	29	30	43	52	46	60	64	36	46	56	67
Arizona	13	14	16	20	17	20	22	18	21	19	22
Utah	39	41	51	52	42	56	31	12	48	51	47
Nevada	4	7	2	8	6	7	4	2	6	6	5
Idaho	43	62	65	81	71	66	75	50	70	60	70
Washington	311	396	372	477	464	536	564	551	595	1,300	1,700
Oregon	375	540	441	554	559	540	525	555	600	672	553
California	1,928	1,887	1,848	2,015	1,634	1,958	1,650	3,124	3,523	3,871	4,096
Total	2,883	3,098	3,009	3,464	2,979	3,461	3,046	4,453	5,240	6,235	6,751
United States (grand total)	8,841	10,431	11,450	11,843	10,108	12,086	11,216	11,874	13,281	12,993	13,628

The annual variation in the pear crop for the years covered by Table I (1909 to 1917) is shown graphically in figure 2.

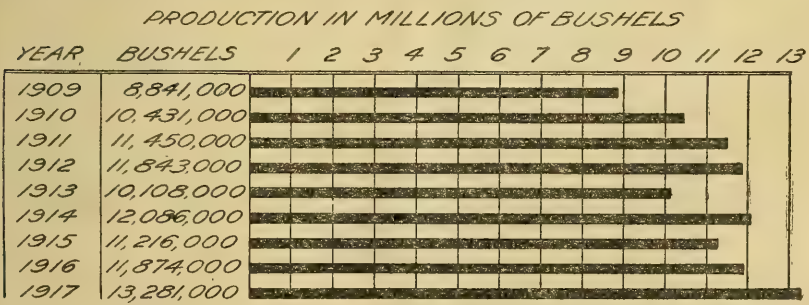

FIG. 2.—Diagram showing the annual farm production of pears (in bushels) in the United States for the 9-year period from 1909 to 1917, inclusive. The estimated farm crop of pears in the United States for 1918 was 10,342,000 bushels; for 1919 (October estimates), 13,687,000 bushels. The estimates of the commercial (in distinction from the farm or agricultural) crop for the past two years are: 1918, 7,589,000 bushels; 1919 (November estimates), 8,422,000 bushels.

Figure 3 shows in a strikingly clear manner the average annual production of pears (in bushels, by States) for the 5-year period, 1912 to 1916, inclusive. As will appear in considering the distribution of the industry, occasional commercial orchards of more or less importance are found in a large proportion of the States, but those in which the industry is of more than local importance are few in number. The commercial industry is located very largely in those States which are shown in figure 3 to have an average annual yield of 450,000 bushels or more, though in several other States, as, for example, Colorado, Utah, Delaware, Texas, and Illinois, there are places where the pear orchards are of more than local importance.

OUTSTANDING FEATURES OF THE PEAR INDUSTRY.

The census figures for 1890, 1900, and 1910 show (in round numbers) 5,100,000, 17,700,000, and 24,000,000 pear trees of all ages in the country, thus indicating a rather constant and considerable increase from year to year. Of the trees recorded in 1910, about 8,800,000 were reported as not of bearing age. No similar segregation of trees of bearing and nonbearing age was made in the census reports of 1890 and 1900.

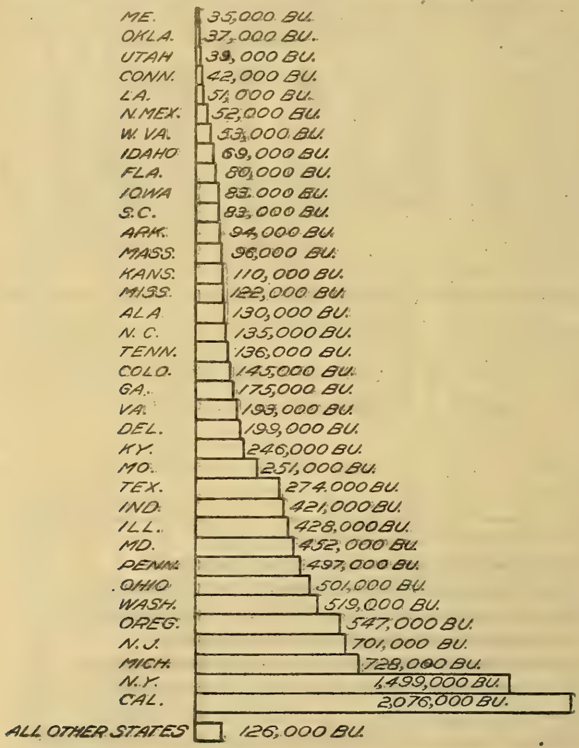

FIG. 3.—Diagram showing the estimated annual average farm production of pears in the principal pear-producing States for the 5-year period from 1912 to 1916, inclusive. The average yearly production for the entire United States for this period was 11,425,000 bushels.

FAIRLY CONSTANT TOTAL PRODUCTION.

The estimates of production shown in Table I and in figure 2 indicate a fairly constant yield for the country since 1910. While the growing of pears for commercial purposes has been extended in recent years in some localities and the industry has been newly established in a few regions, it is also true that many orchards planted for commercial purposes have been destroyed during the last two decades. The conclusion, therefore, is that the increases in the number of trees shown by succeeding census reports are made up principally of trees that represent home interests rather than commercial activities.

MENACE OF FIRE-BLIGHT.

To those familiar with the situation, the outstanding feature in pear growing is the menace of fire-blight. This disease, doubtless more than any other factor, restricts the planting of pears, and in the past it has destroyed great numbers of trees and caused the abandonment of commercial enterprises in many places.

OPPORTUNITY TO EXTEND INDUSTRY NOT GREAT.

Another factor that needs to be considered critically by prospective pear growers is the comparative ease with which the market demand can be supplied. Pears are used in quantity in only a few ways. They are consumed in the fresh state and are canned. In California they are also dried. Otherwise comparatively little use is made of them. The market demand for a fruit that is used in only a very small number of ways is satisfied with a much smaller supply than is the case with a fruit that is used in many different ways. Thus, there is not so large an opportunity in the extension of commercial pear growing as for some other fruits.

PROMINENCE OF THE BARTLETT AND KIEFFER PEARS.

Among pear varieties, the relative prominence of two sorts—the Bartlett and the Kieffer—is conspicuous. These two varieties are to the pear industry of the country what the Elberta variety is to the peach industry, the Washington Navel to the California orange industry, and the Baldwin, Winesap, and Ben Davis varieties to the apple industry. Throughout the northern pear-growing districts, in the Intermountain States and on the Pacific coast, the Bartlett is by far the most widely and extensively planted variety. The Kieffer is also planted, both commercially and for home use, in many of these districts; while in middle latitudes and in the South the Kieffer very largely predominates, because of the comparative resistance of the tree to blight. Further information in regard to the distribution of varieties is given in the pages that follow.

IMPORTANT COMMERCIAL DISTRICTS AND VARIETIES, BY STATES.

NEW ENGLAND STATES.

MAINE.

Distribution.—No important centers of pear production occur in Maine; but occasional orchards of small size are located in several counties in the southern part of the State, including York, Oxford, Cumberland, Androscoggin, Sagadahoc, Kennebec, Lincoln, Knox, Waldo, and possibly in certain localities in the southern sections of the counties to the north of those named.

Varieties.—The varieties commonly planted include the Bartlett, Clapp Favorite, Sheldon, Anjou, Seckel, Bosc, Lawrence, and possibly a few others.

NEW HAMPSHIRE.

Distribution.—Pears in New Hampshire are negligible from a commercial standpoint, and but few are grown for home use. These occur mostly in the southern part of the State.

Varieties.—Bartlett, Sheldon, Howell, Flemish (*Flemish Beauty*), and possibly others are grown.

VERMONT.

Distribution.—Pear growing in Vermont is unimportant commercially, but trees are rather widely distributed, especially in the Lake Champlain district and in Windham County in the southern part of the State.

Varieties.—Bartlett, Clapp Favorite, Howell, Sheldon, Flemish (*Flemish Beauty*), Lawrence, and Winter Nelis are representative sorts in this State.

MASSACHUSETTS.

Distribution.—In an earlier day, eastern Massachusetts was famous for its amateur pear growers. The principal pear interests of the State are still located in that section, especially in the eastern part of Middlesex County in the vicinity of Belmont, Arlington, Concord, and other points not far from Boston. Worcester is also a center of some production.

Varieties.—The principal varieties include the Bartlett, Bosc, Clapp Favorite, Sheldon, Seckel, Danas Hovey, and Anjou.

RHODE ISLAND.

Distribution.—Pears are grown for home and local use, throughout most of Rhode Island, but there are no centers of large production.

Varieties.—Bartlett, Sheldon, and Seckel are the more common sorts.

CONNECTICUT.

Distribution.—There are no communities which are centers of pear production in Connecticut, and the aggregate of the commercial interests is small. There is one large orchard in the extreme southwestern part of the State and small interests in other towns in the same general region, while trees occur in most sections throughout the State.

Varieties.—Bartlett, Anjou, Seckel, and Kieffer are the more common sorts.

MIDDLE ATLANTIC STATES.

NEW YORK.

Distribution.—New York is second only to California in pear production. The commercial interests are located principally in three regions. The largest one is the Lake Ontario district, which includes a large portion of Niagara, Orleans, Monroe, and Oswego Counties, and smaller parts of Cayuga and Onondaga Counties. Pears are also grown in the "finger-lake" region in the central western part of the State and in the Hudson River valley. In the latter, the principal areas are in Columbia and Greene Counties, and smaller interests are found northward in Albany and Rensselaer Counties and southward in Dutchess and Ulster Counties. Pears are also grown to some extent on Long Island and for home use in many parts of the State.

Varieties.—As in many other States, the Bartlett is the most important variety. Others commonly planted include Clapp Favorite, Bosc, Howell, Angouleme, Anjou, Seckel, Lawrence, and Kieffer. In some orchards in the Hudson River valley, where the soil is sandy, the Bosc has not done well. The conviction prevails that it requires a fairly heavy soil in order to succeed.

NEW JERSEY.

Distribution.—Commercial pear orchards occur in considerable numbers in certain sections of New Jersey, the principal interests centering about Moorestown, Beverly, and Riverton in Burlington County, Merchantville in Camden County, Glassboro in Gloucester County, and at various other points in these and other counties in the central part of the State. Most of the centers of production are within a comparatively short distance of Philadelphia, and a considerable proportion of the fruit is marketed there. In production New Jersey ranks third on a 5-year average (fig. 3).

Varieties.—In many orchards the Kieffer has been largely planted, but varieties of better dessert quality, including the Bartlett, Angouleme (*Duchess*), Seckel, and Lawrence, are also grown commercially. The Sheldon, Vermont Beauty, and Anjou are grown to some extent for home use.

PENNSYLVANIA.

Distribution.—There are no well-developed centers of pear production in Pennsylvania. Pears are grown to a limited extent about Philadelphia, Harrisburg, and some of the other cities of importance, and more or less widely for home use.

Varieties.—The widely grown varieties, such as the Bartlett, Seckel, Lawrence, and Kieffer, are most commonly planted.

EAST NORTH-CENTRAL STATES.

OHIO.

Distribution.—The commercial pear interests in Ohio are small. Some orchards occur in the lake region in Lucas, Ottawa, Cuyahoga, and Lake Counties. Otherwise the pears grown are mostly for home and local use. The aggregate production, however, is considerable (fig. 3).

Varieties.—The Bartlett and Kieffer are the principal sorts.

INDIANA.

Distribution.—Little attention is given to pear growing in Indiana. The industry is restricted practically to rather unimportant home plantings.

Varieties.—Such varieties as the Kieffer, Bartlett, Flemish (*Flemish Beauty*), Tyson, and Sheldon are represented.

ILLINOIS.

Distribution.—Most of the pear orchards in Illinois are located in the southern third of the State, with the principal centers of production in Marion, Clay, and Union Counties.

Varieties.—The Kieffer is the most important variety; a few Garber, Howell, Angouleme (*Duchess*), and possibly other sorts also are grown.

MICHIGAN.

Distribution.—The largest commercial pear interests in Michigan are in the southwestern part of the State, in Berrien, Van Buren, and Allegan Counties; but pears are grown in practically all the counties bordering on Lake Michigan and in Oakland and McComb Counties in the southeastern part of the State. They are grown in nearly all counties for home use.

Varieties.—While the Bartlett leads in importance, a considerable number of varieties are grown in the commercial orchards in Michigan. Among them are the Clapp Favorite, Clairgeau, Howell, Bosc, Danas Hovey, Seckel, Angouleme, Anjou, Kieffer, and several others. The early ripening sorts include Summer Doyenne, Giffard, and Bloodgood.

WISCONSIN.

Practically no pears are grown in Wisconsin.

WEST NORTH-CENTRAL STATES.

MINNESOTA.

Practically no pears are grown in Minnesota.

IOWA.

Distribution.—Pear growing is a negligible factor in the fruit industry of Iowa. This is due largely to the destructiveness of blight, while in the northern part the severity of the winter conditions is also a decidedly limiting factor, few varieties being sufficiently hardy to withstand them.

Varieties.—In Extension Bulletin 27 (revised) of the Iowa State College of Agriculture the La Motte (*Bezi de la Motte*), Warner, Seckel, Anjou, Kieffer, Longworth, and Flemish (*Flemish Beauty*) varieties are reported to have shown a considerable degree of hardiness and resistance to blight in some localities in Iowa.

MISSOURI.

Distribution.—There are no very important centers of pear production in Missouri, but small commercial interests are reported in several counties, including St. Louis, Montgomery, Buchanan, Jackson, Greene, and Howell.

Varieties.—The Kieffer is the principal variety, but the Garber, Angouleme, Seckel, Anjou, and possibly others are grown.

NORTH DAKOTA.

Practically no pears are grown in North Dakota.

SOUTH DAKOTA.

Distribution.—Practically no pears are grown in South Dakota. A few pear trees occur in Union, Clay, Yankton, and Bon Homme Counties, which border on the Missouri River in the southeastern part of the State; they are rarely found elsewhere.

Varieties.—In general, the measure of success with all varieties tried has been so small as to discourage the planting of pears in this State.

NEBRASKA.

Distribution.—A few pear orchards are located in southeastern Nebraska in the counties bordering on the Missouri River as far north as the northern border of Washington County; also in Johnson and Pawnee Counties in the second tier from the river in the extreme southeastern part of the State. Elsewhere in the State pear trees are seldom found.

Varieties.—No variety is preeminent, though the Kieffer probably occurs more frequently than any other. Garber, Bartlett, and Seckel are also grown.

KANSAS.

Distribution.—Small plantings are widely distributed, especially throughout the eastern half of the State of Kansas. The commercial interests are small; but a few orchards are located in the four or five northeasternmost counties of the State north of the Kansas River and in Reno, Sedgwick, Sumner, and Cowley Counties in the Arkansas Valley. A few orchards also occur in the eastern part of the State, in the counties bordering the Kansas River on the south.

Varieties.—Several varieties are included in the plantings, such as the Kieffer, Garber, Clapp Favorite, Angouleme (*Duchess*), Seckel, and Douglas. The last-named variety originated in Kansas in Douglas County.[1]

SOUTH ATLANTIC STATES.

DELAWARE.

Distribution.—Pear growing is very generally distributed in Delaware, though considerably more than half the total production is accredited to Kent County. Important areas of production center about Bridgeville, Milford, Camden, Smyrna, and Middletown.

Varieties.—The Kieffer comprises the commercial crop. It is usually considered essential to plant a small proportion of other varieties to insure adequate cross-pollination of the blossoms. The Le Conte and Garber varieties are commonly used for this purpose.

MARYLAND.

Distribution.—A good many orchards of commercial size occur in the Eastern Shore counties, Kent, Queen Annes, and Caroline probably leading. Isolated orchards of importance are also found in other localities, including Anne Arundel, Carroll, Washington, and other counties.

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[1] See the Yearbook of the Department of Agriculture for 1912, p. 267.

Varieties.—The bulk of the fruit consists of the Kieffer, but trees of the Le Conte, Garber, Bartlett, Seckel, Angouleme, Anjou, and a few other varieties are occasionally found.

VIRGINIA.

Distribution.—As in many other States, pear trees are widely distributed, being found in nearly all parts of Virginia, but there are very few commercial orchards and no centralized pear industry. Some car-lot shipments are made from Frederick County.

Varieties.—The Kieffer predominates, but the Garber, Le Conte, Bartlett, Seckel, Sheldon, Lawrence, and some other sorts are sometimes grown.

WEST VIRGINIA.

Distribution.—Very few pears are grown in West Virginia and there are no centers of production.

Varieties.—The Kieffer is found more frequently than any other sort.

NORTH CAROLINA.

Distribution.—The pear is negligible in the fruit industry of North Carolina, though trees are grown more or less in many sections.

Varieties.—The Kieffer is the variety most frequently planted. The Le Conte and Garber varieties are also grown.

SOUTH CAROLINA.

Distribution.—The prevalence of blight has largely restricted the planting of pears, but they are grown in small plantings in most parts of the State.

Varieties.—The sand-pear hybrid group, including the Kieffer, Le Conte, and Garber, comprises practically all the varieties that are planted.

GEORGIA.

Distribution.—Pears are relatively unimportant in Georgia. Orchards and small plantings are located in many parts of the State, and are perhaps of rather greater importance than elsewhere in the southwestern portion, in Grady, Thomas, Brooks, Dougherty, Worth, Crisp, and some other counties. Commercial shipments are made from points in some of these counties.

Varieties.—The Kieffer is the principal variety; some Le Conte, a few Garber, and several others of the sand-pear hybrid group also are grown.

FLORIDA.

Distribution.—In the northern and Panhandle regions of Florida there are some 10 or 12 counties in each of which the pear production, according to the Thirteenth Biennial Report (1913–14) of the

State Department of Agriculture, ranged from about 1,200 to more than 3,200 barrels. Pears are widely distributed in the State, but the interests are too small to be of any special importance. The prevalence of pear blight doubtless has greatly restricted production in this and other Southern States.

Varieties.—The Kieffer and Le Conte comprise most of the plantings.

EAST SOUTH-CENTRAL STATES.

KENTUCKY.

Distribution.—A few pears are grown in Jefferson County and in some other counties along the Ohio River in Kentucky, while small plantings are distributed throughout the State. Even in the aggregate, however, the quantity of fruit grown is small.

Varieties.—The Kieffer and Garber represent practically the total production.

TENNESSEE.

Distribution.—Pears are produced in but very small quantities in Tennessee, though trees are found in small numbers in most sections of the State.

Varieties.—The plantings are confined mostly to the Kieffer, Garber, and Le Conte varieties.

ALABAMA.

Distribution.—Pears are grown here and there throughout the State of Alabama, but not commercially.

Varieties.—The Kieffer is the principal variety. Other varieties of the sand-pear hybrid group, which includes the Le Conte, Garber, and several others, are occasionally planted, especially to provide pollen for fertilizing the Kieffer.

MISSISSIPPI.

Distribution.—Pears are planted more or less widely in the State of Mississippi, but there are no important centers of production. The prevalence of blight doubtless has greatly restricted the growing of this fruit.

Varieties.—The Kieffer and Le Conte are practically the only varieties found.

WEST SOUTH-CENTRAL STATES.

ARKANSAS.

Distribution.—Very few pears are grown in Arkansas. An occasional orchard has been planted in the peach and apple growing sections, and a few fairly large orchards are located in the southern part of the State.

Varieties.—Largely the Kieffer, Le Conte, and Garber, and occasionally other varieties of the sand-pear hybrid group are planted.

LOUISIANA.

Distribution.—Pears are grown in Louisiana for home use only.

Varieties.—Kieffer, Le Conte, Garber, and Koonce are the varieties planted.

OKLAHOMA.

Distribution.—An occasional commercial orchard has been planted in the central and eastern portions of Oklahoma, but there are no centers where pear growing forms an important community interest.

Varieties.—The Kieffer is the principal variety grown commercially, but there are plantings which include the Garber, Bartlett, Angouleme (*Duchess*), and several other sorts of minor importance.

TEXAS.

Distribution.—While pears in considerable quantity are grown in Texas, the producing areas with few exceptions are rather indefinite and correspondingly difficult to define. Probably the most important district for commercial production, potentially at least, is the upper Rio Grande Valley, where, within a distance of 40 miles of El Paso, a great many pear trees have been planted during recent years. Some of the orchards have come into bearing. This district is irrigated from the reservoir made by the Elephant Butte Dam.

Another region in western Texas in which fruit interests, including pear growing on a small scale, are being developed, is located in the general region of Stockton, Pecos County, embracing adjacent parts of four counties, Pecos, Reeves, Jeff Davis, and Brewster. The topography is broken and mountainous, the altitudes of some of the peaks in Jeff Davis County ranging from 5,000 to more than 8,000 feet, though the higher elevations are not included within the fruit-producing area.

In the Panhandle region, pear trees are general; but they represent no important commercial activities.

In the northern portion of the State, extending eastward from the Panhandle region and including an area three to four counties in width, there are grown a good many pears in the aggregate. Some commercial production occurs.

The remaining portions of the State are unimportant from the standpoint of pear production, but trees and an occasional orchard are found widely distributed.

Some years ago many orchards were planted in the Gulf coast region, but most of these proved unsatisfactory because of the prevalence of blight.

Varieties.—In the El Paso district the Bartlett has been largely planted. This, and a few others of the choicer varieties, also the Kieffer, have been planted in the Panhandle region. In other parts of the State, the Kieffer is the principal variety, but the Le Conte, Garber, Smith, and other sorts are also found.

MOUNTAIN STATES.

MONTANA.

Distribution.—There is little or no commercial pear growing in Montana. The climate in the eastern sections of the State is too severe, while blight has been a serious obstacle in maintaining such plantings as have been made in the Bitter Root and other valleys in the western part of the State where fruit-growing interests have been developed.

Varieties.—Such varieties as the Bartlett and Flemish (*Flemish Beauty*) are reported to do well in the western districts, aside from their susceptibility to blight.

IDAHO.

Distribution.—There is a small commercial production of pears in Idaho, principally in the Payette Valley, the Boise Valley, Council Valley, and the Lewiston district. These names signify in general the location of the regions. In limited quantities pears are also grown in most of the other fruit-producing valleys of the State.

Varieties.—The Bartlett variety predominates, but others, including the Flemish (*Flemish Beauty*), Anjou, Winter Nelis, Howell, Clairgeau, and Kieffer, are also planted.

WYOMING.

Distribution.—While there is no pear industry in Wyoming, a very few trees are found in the same districts as the apple. Such apple orchards as have been planted are principally in the valley of the Bighorn River and its tributaries in Bighorn, Washakie, and Hot Springs Counties; in the valley of the Platte River in Natrona, Converse, Platte, and Goshen Counties; and in more or less isolated locations in Crook, Johnson, and Sheridan Counties in the northeastern part of the State.

Varieties.—Information regarding the adaptability of varieties is obviously meager. The Kieffer and Flemish (*Flemish Beauty*) probably are planted more frequently than any other sorts.

COLORADO.

Distribution.—Pears are grown to a limited extent in most of the irrigated valleys of Colorado where fruit interests have been developed, but the commercial orchards are located chiefly in the Canyon City district in Fremont County and in the Grand Valley in Mesa County.

Varieties.—The most important variety is the Bartlett, but the Anjou, Sheldon, Seckel, Lawrence, Winter Nelis, Kieffer, and some others are grown.

NEW MEXICO.

Distribution.—Though pears are of secondary importance commercially in New Mexico, they are grown more or less in several valleys in which a fruit industry has been developed. The principal districts in which pears occur are as follows: The Mimbres Valley district, mostly in Luna County; the Rio Grande Valley district, extending from the southern border of the State as far north as the northern part of Santa Fe County; the Otero County district in the northern part of the county of that name; the Lincoln County district, represented by several small valleys converging toward the southeastern part of that county; the Pecos Valley district, which extends through Eddy County and as far north as Roswell in Chaves County; the Portales district in the eastern part of Roosevelt County, a recently developed fruit-growing section; and the San Juan County district, located along the San Juan River in the northern part of the county.

Varieties.—The varieties commonly grown are the Bartlett, Clapp Favorite, Anjou, and Winter Nelis.

ARIZONA.

Distribution.—Pears are grown in Arizona only to a very limited extent, but they occur more or less widely throughout the agricultural sections of the State, and more especially in the Salt River Valley in Maricopa County east of Phoenix and in the Gila Valley in the central part of Graham County.

Varieties.—The principal varieties are the Bartlett, Winter Nelis, and Kieffer.

UTAH.

Distribution.—The pear-producing districts of Utah correspond rather closely with those apple districts which are south of Ogden, blight having destroyed most of the plantings made in previous years in the districts north of that city. The most important pear district, however, centers about Provo, in Utah County. In this district the orchards are located in the Utah Lake Valley along the streams flowing out of the Wasatch Mountains into that lake. In Weber, Davis, and part of Salt Lake Counties orchards are likewise found in the valleys of the small streams which come from the Wasatch Range and which empty into Salt Lake, while south of Salt Lake City orchards occur in the Jordan Valley.

Varieties.—The more important varieties are the Bartlett, Anjou, Winter Nelis, Lawrence, and Flemish (*Flemish Beauty*).

NEVADA.

Practically no pears are grown in Nevada.

PACIFIC STATES.

WASHINGTON.

Distribution.—Pears are of considerable commercial importance in Washington. They are grown principally in the irrigated valleys where apple and other fruit interests have been developed. The largest production is in the Yakima Valley in Yakima and Benton Counties. The Wenatchee Valley, with the interests centering about the town of Wenatchee, but with some car-lot production at most of the other fruit-shipping stations, is second in importance. Small commercial interests have been developed in the Walla Walla district, in the Okanogan Valley, in the Puget Sound region at various points, and in certain localities in Clarke and Klickitat Counties.

Varieties.—The Bartlett is the variety most extensively grown. Other commercial sorts include the Clapp Favorite, White Doyenne, Flemish (*Flemish Beauty*), Bosc, Clairgeau, Comice, Seckel, Anjou, and Winter Nelis.

OREGON.

Distribution.—Pears are of commercial importance in practically all the fruit-growing districts of Oregon. The most important district, with several thousand acres devoted to this fruit, is in the Rogue River valley, centering about Medford in Jackson County. Several centers of much smaller production are located in the Willamette Valley, in Douglas, Polk, and Marion Counties, and elsewhere; in the Hood River valley; in the Milton-Freewater district; and in the Grande Ronde Valley in the northeastern part of the State.

VARIETIES.—In the Rogue River valley several varieties enter into the industry, the Bartlett, Howell, Clairgeau, Bosc, Comice, Anjou, and Winter Nelis being the most important. Several of these varieties, especially the Bartlett, Anjou, and Winter Nelis, are also grown in most of the other districts. The Clapp Favorite, Flemish (*Flemish Beauty*), and Kieffer occur in some of the orchards in the northeastern sections of the State. A number of other sorts are planted on a scale sufficient to suggest a wide range of adaptability of most of the commercial varieties commonly listed by nurserymen.

CALIFORNIA.

Distribution.—While pears are widely grown throughout most parts of California, the commercial industry is more or less centralized. As reported by the California State Commission of Horticulture (Monthly Bulletin, vol. 5, No. 3, 1916), the counties named in Table II, with acreages in pears indicated, lead in importance.

TABLE II.—*Leading pear-producing counties in California, showing acreages in bearing and nonbearing pear trees in 1915.*

County.	Area in pear orchards (acres).		County.	Area in pear orchards (acres).	
	Bearing age.	Nonbearing age.		Bearing age.	Nonbearing age.
Lake	1,460	1,000	Solano	1,000	230
Placer	1,500	....	Sonoma	1,097	554
Sacramento	3,000	2,000	Los Angeles	311	2,388
Santa Clara	1,400	185	San Luis Obispo	75	3,285

While the last two counties named in Table II are unimportant from the standpoint of present production, the acreages of trees of nonbearing age in those counties are larger than in any others in the State. Several other counties having a relatively small production at present contain from 900 to 1,500 acres of trees not of bearing age. A large total acreage, however, may be made up of a great number of small noncommercial plantings, while a few hundred acres made up of several comparatively large plantings may make a community interest of considerable commercial significance.

Varieties.—The Bartlett variety so largely predominates in nearly all sections of California, both for shipping fresh and for drying, that it may be said practically to constitute the pear industry of the State. It is also the principal variety used for canning. In some sections the Angouleme, Clairgeau, Comice, Easter, P. Barry, Winter Nelis, and a few others are grown.

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EXPERIMENTS WITH KHERSON AND SIXTY-DAY OATS.

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SCOPE OF THE INVESTIGATIONS.

Extensive varietal experiments with Kherson and Sixty-Day oats have been conducted in the United States during the past 15 years. Prior to 1900 these varieties were practically unknown in this country, but to-day they are probably more generally grown than any of the older varieties. In this comparatively short time they have become widely distributed and are now of great commercial importance.

The general popularity of these oats must be attributed largely to their early maturity and their ability to produce high yields. In sections where oats are grown primarily for market they have not met with favor because of their yellow color, but the small thin-hulled grains are highly regarded by farmers for feeding.

Varietal experiments including the Kherson and the Sixty-Day oats have been conducted by the State agricultural experimental stations and the United States Department of Agriculture for periods varying from 4 to 14 years. The large mass of data now available indicates quite definitely the adaptability of these varieties to the different sections of the United States and their value in comparison with other oats. It is the purpose of this bulletin to assemble these data and to present such conclusions as they appear to warrant.

SOURCES OF DATA.

Three sources of data have been drawn upon for this publication, viz, the results of experiments conducted independently by the United States Department of Agriculture, of those conducted cooperatively by the United States Department of Agriculture and the State agricultural experiment stations, and those conducted independently by the State agricultural experiment stations. Data from the last-mentioned source are included in order to present fully the present status of the Kherson and Sixty-Day varieties in the United States. Full credit is given in all cases where such data are used. In a number of instances where results have not been published recently the experiments have been summarized for this bulletin by officials of the various stations.

The data presented herein have been obtained under a wide range of climatic and soil conditions. However, the varietal yields obtained at any one place should be fairly comparable, while the data from several stations in the same general area supplement each other. At nearly all stations the aim has been to grow the varieties in the varietal experiments under conditions similar to those on the best farms in the localities where the experiments were conducted.

Those experiments which have been conducted under similar conditions have been grouped whenever practicable. The results obtained in the eastern half or humid portion of the United States are presented first, followed by those obtained in the western half or semiarid portion, including the results of a few experiments on irrigated land.

In addition to the presentation of data on yield of grain, brief statements on yield of straw, weight per bushel, percentage of hull, and the improvement of Kherson and Sixty-Day oats are included in this bulletin.

HISTORY OF KHERSON AND SIXTY-DAY OATS.

Both the Kherson and the Sixty-Day oats were introduced into the United States from southern Russia. The first lot of the Kherson oats sent to this country was obtained by the Nebraska Agricultural Experiment Station (24)[1] in 1896 through Prof. F. W. Taylor, then superintendent of farmers' institutes in Nebraska, while traveling through Russia. As it was obtained in the Kherson Government, the name "Kherson" was given to it. Seed of the Sixty-Day variety was received by the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry[1] on March 6, 1901, from Dr. S. de Mrozinski, of Proskurov, in the Podolia Government of Russia. This province is adjacent to and just west of the Kherson Government, and has essentially the same climatic and soil conditions. Both these varieties have been widely distributed in the United States, though probably the Sixty-Day is most widely grown. The origin of the Kherson oat is not definitely known. The Sixty-Day is said to have been originated by Dr. Mrozinski, but no information is at hand regarding the source of the material from which he made his selection. It is very probable, however, that the Kherson is from the same original stock, as the two varieties are practically identical in every way and were obtained from adjoining provinces. A field of Sixty-Day oats in shock near Dickinson, N. Dak., is shown in figure 1.

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[1] The serial numbers in parentheses refer to "Literature cited" at the end of the bulletin.

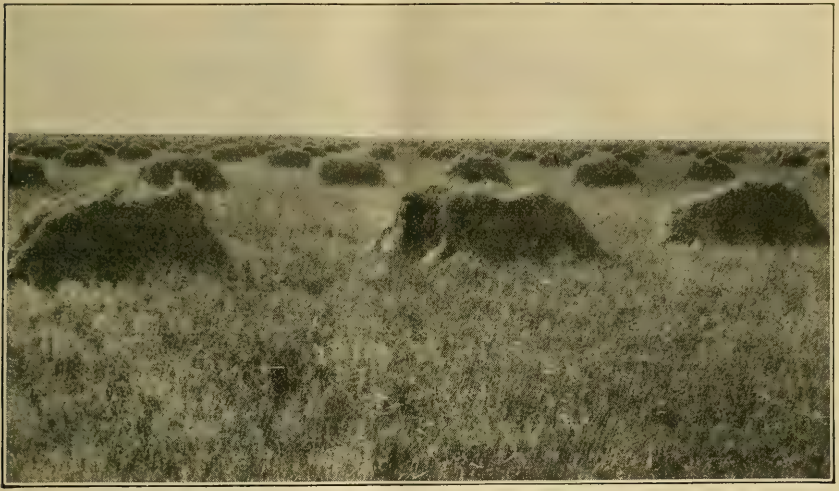

FIG. 1.—A field of sixty-day oats in shock near Dickinson, N. Dak.

A brief account of the section of Russia from which these varieties were obtained will be of value for comparison with soil and climatic conditions in the United States. As is pointed out in the following quotation from Carleton (9, pp. 8, 9), the Russian grain-producing region, of which the Kherson and Podolia Governments are a part, is very similar to our upper Mississippi Valley and central Great Plains areas.

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[1] "S. P. I. No. 5938, *Avena sativa.* From Proskurow, Russia. Received through Dr. S. de Mrozinski March 6, 1901. Sixty-Day, originated by Dr. Mrozinski." (47, p. 44.)

An earlier importation from Dr. Mrozinski was unnamed, but undoubtedly is identical with the Sixty-Day. It was grown at a few agricultural experiment stations under the name of "Seventy-five Day," but was not widely distributed and soon became merged with the introduction just mentioned. The exact date when this importation was made is not stated in the record, but it was about June 1, 1900. The record is as follows:

> "5168. *Avena sativa.* From Proskurow, Russia. Presented by Dr. S. de Mrozinski. An early variety which ripens within 75 days from the seed." (46, p. 57.)

The soil of the greater portion of the grain region of Russia and Siberia is well known in that country as the "Chernozem" or "black earth." It is a broad belt of prairie, 600 to 700 miles in average width, beginning in Hungary and extending northeastward to the Ural Mountains, and then eastward into Siberia to unknown boundaries. On the north and west are "the gray forest lands" and on the south and east are salt and alkaline districts and sandy wastes, and finally the Caucasus and Ural Mountains. By both chemical and mechanical analyses the soil is shown to be remarkably similar to that of our own prairies, also commonly known by the similar term of "black loam." The depth is on an average, probably a little greater than that of our prairie soil. * * *

The similarity between the Russian steppes and the Great Plains is fully as great in climate as in soil, both regions being emphatically continental and subject to great extremes of temperature and moisture. In the greater portions of the two regions the winters are long and very severe, while the summers, though short, are intensely hot. Other noteworthy features of the climate are (1) the great number of clear days in the year, (2) the extreme amount of precipitation during two or three months of the summer as compared with that of the remainder of the year, (3) the character of this precipitation, falling in quick thunderstorms, as a rule, with very few days of mists or fogs, (4) the excessive heat of midsummer, following intensely cold winters, as already mentioned, and (5) the comparatively light snowfall. These features, while common to the two regions, are considerably more pronounced for corresponding portions of the grain belt in Russia than in the United States. For this reason varieties brought from Russia are all the better adapted for cultivation in this country, as they are already used to even more rigorous conditions of climate than they will have to endure here. The snowfall, as a rule, is less on the Russian steppes than on the Great Plains. The rainfall is generally considerably less, and the extremes of temperature a little greater.

DESCRIPTION OF KHERSON AND SIXTY-DAY OATS.

Botanically, the Kherson and the Sixty-Day oats can not be distinguished one from the other. Typical panicles and spikelets of these varieties are shown in figure 2. While these so-called varieties sometimes differ considerably in yield when grown under the same conditions, the difference is often no greater than that between two commercial strains of the same variety. Since the varieties are identical and the names, therefore, are synonymous, only one description is given.

Kherson, or Sixty-Day.—Early growth erect. Culms slender, stiff, glabrous or slightly pubescent at the nodes, 75 to 110 cm. tall. Sheaths deep green, glabrous; culm leaves 4 to 6, narrow, fine. Peduncle slender, straight, 30 to 45 cm. long, well exserted. Panicle equilateral, short, ovate; rachis nodes 6 to 7; branches short, slender, ascending, scabrous. Spikelets 25 to 50 or more, usually 2-flowered, sometimes 3-flowered. Empty glumes 20 to 22 mm. long, 5.5 to 6.5 mm. wide, usually 9-veined, grayish green before maturity. Lower lemma 14.5 to 16.5 mm. long, narrow, glabrous, varying from deep yellow to nearly white, the yellow predominating but becoming paler in semiarid sections or in dry years; basal hairs few or wanting; awns few or wanting, slender, weak, 20 to 25 mm. long. Upper lemma 10.5 to 12 mm. long, slender, plump, awnless.

The Kherson and Sixty-Day are early in maturing, ripening from 90 to 100 days after sowing, or about 10 to 15 days earlier than most other varieties. It is the earliness of these varieties which has made them particularly valuable in the corn belt and in the Great Plains area. Because of their earliness they are enabled to escape to some extent injury by drought, storms, and rust.

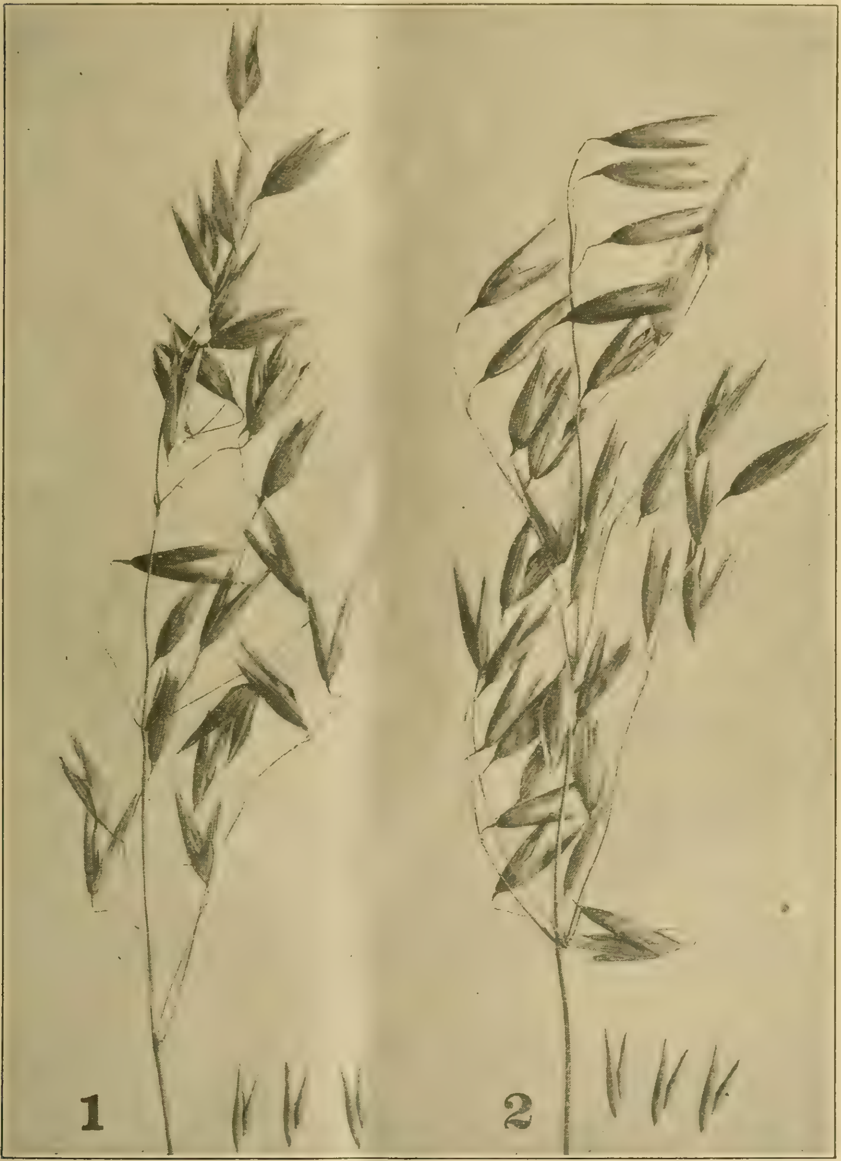

FIG. 2.—Panicles and spikelets of two early yellow varieties of oats; 1, Kherson; 2, Sixty-Day.

EXPERIMENTAL DATA.

While experiments with the Kherson and Sixty-Day oats were begun soon after their introduction into this country, these oats were not generally grown in varietal experiments in field plats until about 1904. Within the following three or four years these varieties were generally included in varietal experiments by the agricultural experiment stations, particularly those in the corn belt and in the Great Plains area. Some of these experiments are still in progress, while others have been discontinued. Most of these experiments were continued long enough to furnish definite evidence regarding the adaptability of the variety to the locality.

VARIETAL EXPERIMENTS IN THE EASTERN HALF OF THE UNITED STATES.

Kherson and Sixty-Day oats have been included in practically all the varietal experiments with spring oats conducted in the eastern half, or humid area, of the United States. Results obtained at 23 experiment stations located in 17 States are presented herein. For the most part, these experiments have been conducted in the North-Atlantic, the east North-Central, and the west North-Central groups of States.

The experiments at Ithaca, N. Y., Ames, Iowa, McPherson, Kans., and Brookings, S. Dak., have been conducted cooperatively by the United States Department of Agriculture and the State agricultural experiment stations of those States, respectively. The experiments at Orono, Me., Durham, N. H., State College, Pa., Wooster, Ohio, La Fayette, Ind., De Kalb, Fairfield, and Urbana, Ill., St. Paul, Crookston, and Grand Rapids, Minn., Fargo, N. Dak., Lincoln, Nebr., Manhattan, Kans., Knoxville, Tenn., Carthage, Mo., Fayetteville, Ark., and Denton, Tex., have been conducted independently by the agricultural experiment stations of the respective States.

In order to interpret experimental results properly, a knowledge of the principal physical factors influencing plant growth is essential. Such information as is available regarding these factors is shown in Table I.

According to the data shown in Table I, the average annual precipitation exceeds 40 inches at Orono, Me., Knoxville, Tenn., and Fayetteville, Ark. At the remaining stations except those in Minnesota, the Dakotas, and Nebraska, the average annual precipitation is above 30 inches. Though occasional droughts occur, some of which are so long continued and so severe as to cause serious damage, the rainfall throughout this area is usually sufficient for crop growth.

In most of the area under discussion summer temperatures are high. Except in New England and the Dakotas the mean temperature during July is about 70° F. at all stations and above this point during August at all except a few. The mean temperature during June ranges from 61.9° at Orono, Me., to 78.7° at Denton, Tex., exceeding 70° as far north as Indiana, Illinois, and Nebraska.

TABLE I.—*Altitude, average annual precipitation, mean seasonal temperatures, and general soil types at 23 experiment stations in the eastern half of the United States.*

[The circled figures in column 4 indicate the number of years during which the data were recorded when such period was more than the number of years shown in column 3.]

Station.	Altitude.	Climatological data.					Soil type.
		Length of record.	Average precipitation.	Mean temperatures (°F.).			
				June.	July.	Aug.	
1	2	3	4	5	6	7	8
	Feet.	*Years.*	*Inches.*				
Orono, Me.	129	35	㊵ 43.18	61.9	66.9	65.0	Light, sandy loam to medium clay loam.
Durham, N. H.[1]	....	38	(56) 39.82	64.4	69.1	66.6	Clay and clay loam.
Ithaca, N. Y.	800	31	(53) 32.97	66.2	70.6	68.2	Clay loam and gravelly loam.
State College, Pa.	1,191	21	㉕ 38.94	66.9	70.7	68.7	Clay loam (Hagerstown).
Wooster, Ohio.	1,030	24	㉟ 38.73	67.8	71.4	68.9	Silt loam.
La Fayette, Ind.	617	29	38.29	70.7	74.6	72.6	
De Kalb, Ill.[2]	....	28	35.64	67.8	71.9	69.6	Brown silt loam.
Fairfield, Ill.	495	15	⑲ 38.61	73.6	77.8	75.9	Gray silt loam or light clay.
Urbana, Ill.[3]	....	24	35.74	70.8	74.8	72.7	Brown silt loam.
Madison, Wis.	974	31	(51) 31.25	67.3	72.0	69.8	
St. Paul, Minn.	848	38	(73) 27.80	67.2	72.0	69.7	
Crookston, Minn.	863	20	23.01	63.5	68.2	65.8	Clay loam (Fargo) and fine sandy loam (Fargo).
Grand Rapids, Minn.[4]	....	22	28.05	....	....	....	
Fargo, N. Dak.[5]	935	28	24.91	64.0	67.8	65.8	
Brookings, S. Dak.	1,636	20	㉑ 20.66	64.5	69.4	67.6	Sandy loam.
Ames, Iowa[6]	....	15	32.86	....	....	....	Black prairie loam.
Lincoln, Nebr.	1,189	26	㉞ 28.43	71.2	75.8	74.8	
Manhattan, Kans.	1,100	47	(51) 31.12	74.5	78.7	76.8	
McPherson, Kans.	1,495	17	⑳ 32.32	73.5	78.1	78.5	Sandy loam.
Carthage, Mo.[7]	....	31	41.55	....	....	....	Brown silt loam (Crawford).
Fayetteville, Ark.	1,451	18	㉓ 46.76	73.7	77.4	76.3	Heavy clay and clay loam.
Knoxville, Tenn.	977	33	㊸ 48.35	73.4	76.2	74.7	
Denton, Tex.[8]	....	9	⑮ 34.45	78.7	82.3	81.8	

[1] Data recorded at Concord, about 30 miles northwest of Durham; altitude at Concord, 350 feet.

[2] Data recorded at Sycamore, about 6 miles northeast of De Kalb; altitude at Sycamore, 855 feet.

[3] Data recorded at Philo, about 8 miles south of Urbana; altitude at Philo, 700 feet.

[4] Data recorded at Pokegama Falls, about 7 miles northwest of Grand Rapids; altitude at Pokegama Falls, 1,290 feet.

[5] Data recorded at Moorhead, just opposite Fargo, in Minnesota; altitude at Moorhead, 935 feet.

[6] Data recorded at Ogden, 22 miles west of Ames; altitude at Ogden, 1,134 feet.

[7] Data recorded at Carthage 16 years; at Sarcoxie, about 13 miles southeast of Carthage, 8 years; and at Joplin, about 13 miles southwest of Carthage, 7 years; altitude at Joplin, 979 feet.

[8] Data recorded at Decatur, about 30 miles west of Denton; altitude at Decatur, 1,047 feet.

RESULTS IN THE NORTH ATLANTIC STATES.

In New England, the agricultural experiment stations of Maine and New Hampshire report varietal experiments with Sixty-Day and Kherson oats. The former station has conducted a rather extensive series of experiments with oats since 1910, including both commercial and pure-line strains of the Kherson variety. No recent varietal work has been reported by the New Hampshire station, but a limited number of varieties, including the Sixty-Day, were tested in 1904 and in the 4-year period from 1906 to 1909, inclusive.

The New York (Cornell) and the Pennsylvania agricultural experiment stations also report varietial experiments which include the Kherson and Sixty-Day oats.

Results in Maine.

The annual and average yields of the Kherson and of seven other varieties of oats grown at the Maine Agricultural Experiment Station at Orono (41, 42, 43) during the 6-year period from 1910 to 1915, inclusive, are shown in Table II.

TABLE II.—*Annual and average yields of the Kherson and of seven other commercial varieties of oats grown at the Maine Agricultural Experiment Station (at Orono) during the 6-year period from 1910 to 1915, inclusive.*

[Data compiled from Maine Agricultural Experiment Station Bulletins 229 and 250 (41 and 43).]

Group and variety.	Yield per acre (bushels).						
	1910	1911	1912	1913	1914	1915	Average.
Early yellow: Kherson	69.4	47.8	52.7	60.8	82.7	66.8	63.4
Midseason yellow: Imported Scotch[1]	60.0	62.4	62.2	67.7	87.1	64.8	67.4
Midseason white:							
Banner	70.8	45.8	62.6	62.7	94.5	81.8	69.7
Prosperity	65.5	52.8	67.4	63.0	92.1	74.1	69.2
Irish Victor	70.5	55.6	61.6	67.0	82.4	76.2	68.9
Swedish Select	72.1	40.9	56.5	60.9	79.9	68.3	63.1
Late white (side): Senator	53.5	38.3	53.5	51.7	83.6	57.9	56.4

[1] The identity of this variety is not definitely known.

The data in Table II show rather conclusively that the midseason varieties outyield the Kherson at Orono. Banner and Prosperity, the leading midseason varieties, have exceeded the Kherson in 6-year average yield by 6.3 and 5.8 bushels, respectively. On the other hand, the Kherson has outyielded the Senator, a late side oat, by 7 bushels.

Several pure lines of the Kherson have been tested at the Maine station, but proved to be decidedly inferior to pure lines of Banner, Irish Victor, and Imported Scotch and therefore were discarded.

Results in New Hampshire.

The annual and average yields of the Kherson and four other varieties of oats grown at the New Hampshire Agricultural Experiment Station at Durham (44, p. 141–146) for two or more years of the 4-year period from 1906 to 1909, inclusive, are given in Table III. Although several varieties were grown in 1904, no data on yields are available, as all varieties were destroyed by rust.

The data in Table III are not sufficient to determine the value of the Kherson oat for New Hampshire conditions. However, they indicate that the early varieties are of some promise, because they usually escape the rust and for that reason may outyield the midseason varieties in a series of years. In the two years for which yields of Kherson are reported it averaged slightly better than any other variety.

TABLE III.—*Annual and average yields of the Kherson and four other varieties of oats grown at the New Hampshire Agricultural Experiment Station (at Durham) during two or more years in the 4-year period from 1906 to 1909, inclusive.*

[Data compiled from New Hampshire Agricultural Experiment Station Bulletin 145 (44, p. 141–146).]

Group and variety.	Yield per acre (bushels).					
	1906	1907	1908	1909	Average.	
					1906 to 1909	1908 and 1909
Early yellow: Kherson	....	....	34.6	36.6	....	35.6
Midseason yellow:						
Hamilton	31.6	68.1	25.5	31.9	39.3	28.7
Welcome [1]	38.1	52.5	24.3	40.0	38.7	32.2
Midseason white: Lincoln	24.1	57.5	31.0	35.8	37.1	33.4
Late white (side): Long's White Tartar	35.3	68.7	31.5	33.1	42.2	32.3

[1] The true Welcome is a midseason white variety.

Under date of November 26, 1917, Prof. F. W. Taylor, agronomist, writes:

> We have not grown any Kherson oats since 1909, and for that reason have no data other than that published in Bulletin 145. Everything considered, I do not think the Kherson oat is as well adapted to New Hampshire as some other strains like the Lincoln and Long's White Tartar. What we need here is an oat that does not run too much to straw and one which has at least some rust-resisting qualities.

Results in New York. [1]

At the Cornell University station (Ithaca) (23) the oat varietal experiments have been conducted in cooperation with the United States Department of Agriculture since 1907. While several pure-line selections of the Sixty-Day oat have been included in these experiments, only one (No. 5938–1) has been of sufficient promise to warrant its retention throughout the entire 11-year period from 1907 to 1917, inclusive. The annual and average yields of two pure-line selections of the Sixty-Day, six selections from other varieties, and two unselected commercial varieties grown at Ithaca in seven or more years of the 11-year period from 1907 to 1917, inclusive, are shown in Table IV.

The data in Table IV indicate clearly that the midseason white varieties will outyield the early yellow varieties in New York. The difference between the highest yielding Sixty-Day selection (5938–1) and the Welcome selection (123–5), the leading variety at Ithaca, is 4.2 bushels. However, the Sixty-Day selection approaches the midseason varieties more closely in yield than might generally be expected and in unfavorable years may surpass them.

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[1] Data since 1913 are from unpublished annual reports of Dr. H. H. Love, collaborator, and Mr. W. T. Craig, agent, to the Office of Cereal Investigations.

TABLE IV.—*Annual and average yields of two pure-line selections of the Sixty-Day variety, six other pure-line selections, and two commercial varieties of oats grown at the Cornell University Agricultural Experiment Station, Ithaca, N. Y., during seven or more years in the 11-year period from 1907 to 1917, inclusive.*

Data obtained in cooperation with the Cornell Agricultural Experiment Station.]

Group and variety.	Pedigree No.	Yield per acre (bushels).													
													Average.		
		1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1907 to 1913	1907 to 1917	1911 to 1917
Early yellow:															
Sixty-Day selection	[1]5938–1	60.0	55.0	56.9	57.5	49.5	55.2	55.7	51.6	73.6	43.4	47.7	55.7	55.1	53.8
Do.	62–II–6–2	63.7	65.0	43.3	59.8	50.2	41.5	46.3	....	....	....	....	52.8	....	....
Early white:															
Pringle Progress selection	131–19	37.5	40.0	35.7	50.6	54.4	56.5	55.7	....	....	....	....	47.2	....	....
Early red:															
Burt selection	33a1–15	41.2	58.7	44.2	64.8	47.2	51.4	53.8	....	....	....	....	51.6	....	....
Do.	63–I–4	42.5	57.5	39.9	62.3	46.2	50.2	52.4	....	....	....	....	50.1	....	....
Midseason white:															
Welcome selection	123–5	53.7	67.5	46.8	61.2	64.0	69.8	68.9	46.1	80.4	48.9	45.3	61.7	59.3	60.5
Silvermine selection	125–20	52.5	40.0	43.6	56.0	88.4	72.9	68.2	43.1	76.2	49.2	45.2	60.2	57.8	63.3
Do.	120–9	57.5	42.5	48.3	62.7	62.0	67.3	69.5	45.8	75.2	47.3	39.6	58.5	56.2	58.1
Silvermine[2]	....	....	....	....	....	70.7	66.3	71.3	44.2	76.6	44.9	48.3	....	....	60.3
Lincoln	....	....	....	....	....	58.9	70.4	70.2	42.1	72.3	47.2	40.1	....	....	57.3

[1] The original strain, Seed and Plant Introduction No. 5938, is grown elsewhere under Cereal Investigations No. 165.

[2] Plant Breeding No. 1571.

In 1911, several representative unselected commercial varieties were added to the experiments at Cornell University, which previous to that time had included mostly pure-line selections from hybrids and from commercial varieties. Among these were Sixty-Day, Silvermine, and Lincoln. The unselected Sixty-Day yielded so much less than the selection 5938–1 that it was discarded at the end of three years, but the other two varieties are still included. The 7-year (1911–17) average yield of the Silvermine is 60.3 bushels; of the Lincoln, 57.3 bushels; and of the Sixty-Day selection (5938–1), 53.8 bushels.

Results in Pennsylvania.

The Pennsylvania Agricultural Experiment Station at State College (15) has included the Sixty-Day variety in its experiments since 1907 and the Kherson variety since 1909. The results to and including 1910 have been published. The annual and average yields of these and seven other varieties in two or more years of the 4-year period from 1907 to 1910, inclusive, are shown in Table V.

As shown in Table V, the Sixty-Day oat during the 4-year period from 1907 to 1910, inclusive, outyielded all others at State College. The 2-year data on the Kherson indicate that it will do equally as well as the Sixty-Day in central Pennsylvania.

No data on oat varietal tests have been published by the Pennsylvania station since 1911, but Prof. C. F. Noll, associate professor of experimental agronomy, has kindly summarized the more recent investigations. In a letter dated December 11, 1917, he states that of 27 varieties grown during the seven years from 1911 to 1917 the Kherson ranks sixth and the Sixty-Day eighth. In the three years 1915, 1916, and 1917, however, these varieties rank first and third, respectively, among 30 varieties grown. In the 7-year period from 1911 to 1917, inclusive, the Fourth of July ranks first, with an average yield of 64.6 bushels to the acre. In the same period the Kherson averaged 63.0 and the Sixty-Day 62.2 bushels. In the three years, 1915, 1916, and 1917, Kherson ranks first, with an average yield of 78.4 bushels; New Zealand second, 75.9 bushels; Sixty-Day third, 75.8 bushels; and Fourth of July fourth, 75.7 bushels. In yield of straw the Kherson and Sixty-Day are consistently lowest of all, a characteristic which leads Prof. Noll to remark:

> In some sections where little or no wheat is grown and straw is relatively valuable we find these varieties objected to on account of their rather low yields of straw.

TABLE V.—*Annual and average yields of the Kherson, Sixty-Day, and seven other varieties of oats grown at the Pennsylvania Agricultural Experiment Station (at State College) during two or more years in the 4-year period from 1907 to 1910, inclusive.*

[Data compiled from Pennsylvania Agricultural Experiment Station Bulletin 108 (15).]

Group and variety.	Yield per acre (bushels).					
	1907	1908	1909	1910	Average.	
					1909–1910	1907–1910
Early yellow:						
Sixty-Day	68.7	55.0	56.9	77.5	67.2	64.5
Kherson	....	....	61.5	69.3	65.4	....
Midseason white:						
Japan	65.3	[1]49.5	[2]57.5	[3]67.8	62.7	60.0
Fourth of July[4]	62.7	45.3	56.9	71.7	64.3	59.2
Czar of Russia	64.0	40.3	56.7	71.8	64.3	58.2
Big Four	64.4	44.5	58.8	64.8	61.8	58.1
Swedish Select	61.0	44.6	60.9	65.4	63.2	58.0
Midseason black:						
Joanette	63.2	51.5	62.0	66.0	64.0	60.7
Late white (side):						
Long's White Tartar	64.0	45.8	58.2	79.7	69.0	61.9

[1] Average of 12 check plats.
[2] Average of 8 check plats.
[3] Average of 13 check plats.
[4] Probably identical with Irish Victor.

Prof. Noll further states that where oats are sold the Sixty-Day and Kherson are objected to because of the small size and yellow color of their grain.

Conclusions.

The average yield of the leading variety in each group, at the stations included in the North Atlantic States, is shown graphically in figure 3.

The data presented in Tables II and III indicate that under New England conditions the midseason varieties will outyield the Kherson and the Sixty-Day. In Maine such varieties as Banner, Prosperity, and Irish Victor have averaged several bushels more than the Kherson in a 6-year test. Yields of the Kherson have been reported for only two years at the New Hampshire station. In these years it has slightly outyielded the midseason varieties, but the data are too meager to justify any definite statement regarding its behavior over a longer period.

The results shown in Tables IV and V indicate that the early varieties, Kherson and Sixty-Day, are high yielders in the North Atlantic States. However, the midseason white varieties have outyielded the Sixty-Day under western New York conditions and are therefore recommended for that State. The results obtained at State College indicate that for the higher central and western portions of Pennsylvania and for western Maryland, northwestern Virginia, and West Virginia, the Sixty-Day and Kherson will probably outyield all other varieties.

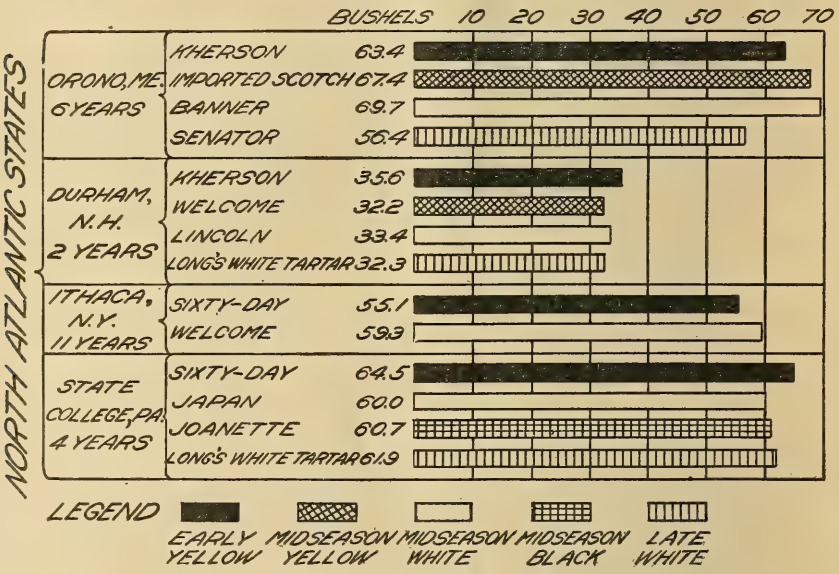

FIG. 3.—Diagram showing the average yields, in bushels per acre, of the highest yielding variety of each of several groups of oats at four experiment stations in the North Atlantic States during the periods of years indicated.

RESULTS IN THE EAST NORTH-CENTRAL STATES.

The section designated as the east North-Central States includes the States of Ohio, Indiana, Michigan, Wisconsin, and Illinois. The agricultural experiment stations in all these States except Michigan have reported varietal experiments in which the Kherson, or Sixty-Day, or both have been included.

The Ohio station has included the Sixty-Day in very extensive varietal tests at Wooster since 1904. In 1908 two selections from the Sixty-Day were added. At the Indiana station both the Sixty-

Day and Kherson were grown from 1905 to 1908. Reports of varietal experiments at this station since 1908 have not included these varieties. At the Illinois station at Urbana the Sixty-Day has been grown since 1905, and it has also been included in varietal trials at De Kalb and Fairfield for several years. Yields of oat varieties at the Wisconsin station have not been published since 1907; both the Sixty-Day and the Kherson were grown that year and in the two years previous.

Results in Ohio.

The annual and average yields of three strains of the Sixty-Day and of thirteen other high-yielding varieties and selections grown at the Ohio Agricultural Experiment Station at Wooster (49 and 51) for five or more years of the 9-year period from 1904 to 1912, inclusive, are presented in Table VI.

TABLE VI.—*Annual and average yields of the original Sixty-Day variety, two selections from that variety, and thirteen other high-yielding varieties and selections of oats grown at the Ohio Agricultural Experiment Station (at Wooster) during five or more years in the 9-year period from 1904 to 1912, inclusive.*

[Data compiled from Ohio Agricultural Experiment Station Bulletin No. 257 (51).]

Group and variety.	Yield per acre (bushels).										
	1904	1905	1906	1907	1908	1909	1910	1911	1912	Average.	
										1908 to 1912	1904 to 1912
Early yellow:											
Sixty-Day	87.2	55.6	71.4	57.0	75.7	71.7	70.9	51.3	73.3	68.6	68.2
Sixty-Day selection, Ohio 7009 (white)	......	......	......	......	75.3	76.9	74.0	53.2	82.1	72.3	......
Sixty-Day selection, Ohio 6106	......	......	......	......	68.5	77.6	73.8	59.0	77.1	71.2	......
Midseason white:											
Siberian	93.7	65.1	78.9	49.1	65.6	71.4	76.6	67.4	74.3	71.1	71.3
Siberian selection, Ohio 6203	......	......	......	......	71.4	73.1	74.1	70.7	78.2	73.5	......
Big Four	82.3	68.5	83.2	49.2	58.4	67.0	75.8	69.8	80.0	70.2	70.5
Silvermine	84.1	64.5	82.6	47.1	60.1	67.4	72.1	71.0	79.4	70.0	69.8
Improved American	85.7	59.5	87.2	45.5	67.2	73.5	63.5	65.8	77.1	69.4	69.4
Improved American selection, Ohio 6222	......	......	......	......	70.6	73.8	64.7	67.2	77.7	70.8	......
Czar of Russia	71.7	63.7	81.6	45.7	71.0	70.0	66.9	61.9	79.7	69.9	68.0
American Banner	83.4	58.2	77.6	47.8	65.8	67.0	64.6	70.1	75.2	68.5	67.7
Lincoln	76.5	60.2	81.0	46.6	61.8	66.7	65.7	67.6	79.9	68.3	67.3
Green Mountain	82.5	59.0	88.1	45.0	68.9	69.3	53.6	59.0	77.1	65.6	66.9
Midseason black:											
Joanette	79.8	66.4	81.3	43.6	73.7	67.4	51.9	62.4	78.8	66.8	67.3
Late white (side):											
Long's White Tartar	73.7	44.3	87.0	50.6	51.1	66.1	76.9	64.7	72.0	66.2	65.2
Storm King	......	......	80.1	44.3	51.1	66.7	79.3	59.6	67.0	64.7	......

Reference to Table VI shows that the Sixty-Day ranks fifth among the commercial varieties which have been tested at Wooster during the 9-year period from 1904 to 1912, inclusive, with an average yield of 68.2 bushels. The highest yielding variety in this period was the Siberian, with an average yield of 71.3 bushels. The Siberian is a midseason white oat, as are also the other three varieties which outyielded the Sixty-Day, viz, Big Four, Siberian, and Improved American. On the other hand, the Sixty-Day has outyielded the late white (side) oat White Tartar by a little more than 3 bushels per acre annually in the nine years that both varieties were grown.

In the most recent publication on oats issued by the Ohio station, the ten leading varieties with an 11-year average yield of 65 bushels or more are listed. Their rank, with yields for 1913 and 1914 added, was as follows: (1) Siberian, (2) Improved American, (3)Big Four, (4) Silvermine, (5) Green Mountain, (6) American Banner, (7) Sixty-Day, (8) Lincoln, (9) Czar of Russia, and (10) Joanette.

The two selections of Sixty-Day listed in Table VI have outyielded the parent variety by several bushels each. The higher yielding of the two selections has averaged 72.3 bushels, as compared with 73.5 bushels for the Siberian selection. The one other midseason white selection listed, that from Great American, has fallen below both the Sixty-Day selections in average yield. The behavior of these selections indicates that certain pure lines of the Sixty-Day are among the best for growing in Ohio under conditions similar to those at Wooster.

Results in Indiana.

In Table VII the average yields of the Kherson, the Sixty-Day, and eight other varieties for the 4-year period from 1905 to 1908, inclusive, are presented. Annual yields have not been reported by the Indiana Agricultural Experiment Station (50).

TABLE VII.—*Average yields of the Kherson, the Sixty-Day, and eight other varieties of oats grown at the Indiana Agricultural Experiment Station (at La Fayette) during the 4-year period from 1905 to 1908, inclusive.*

[Data compiled from Indiana Agricultural Experiment Station Newspaper Bulletin 147 (50).]

Group and variety.	Yield per acre.	Group and variety.	Yield per acre.
Early yellow:	*Bushels.*	Midseason white—Continued.	*Bushels.*
Sixty-Day	47.2	Goldmine	50.8
Kherson	42.4	Czar of Russia	50.5
Early red:		Big Four	50.0
Red Rustproof (Texas Red)	48.7	Improved American	49.5
Midseason white:		Green Mountain	49.3
Great Dakota	54.0	Lincoln	48.8

The results obtained at the Indiana station with early oats have been disappointing. The data in Table VII indicate that the Kherson and the Sixty-Day varieties were not high yielders at La Fayette, having been outyielded considerably by the best of the midseason white varieties. Of 34 varieties included in the varietal tests during the 4-year period from 1905 to 1908, 10 of which are listed in Table VII, the Sixty-Day ranked sixteenth and the Kherson twenty-ninth in average yield per acre. The one representative of the Red Rustproof group, Texas Red, as shown in Table VII, outyielded the Sixty-Day variety by 1.5 bushels in the 4-year period.

Results in Michigan.

No results of varietal tests of oats at the Michigan station have been published for many years. Such information as is available, however, indicates that midseason and late oats are to be preferred to the Sixty-Day and Kherson for growing in that State. The Worthy and the Success, midseason white varieties developed by the agricultural experiment station at East Lansing, are particularly recommended. In a recent letter, Prof. Frank A. Spragg, plant breeder of the Michigan station, says:

> We have had a number of strains of Sixty-Day and Kherson at various times in our varietal tests, but have never gotten as good yields as from the midseason and late varieties. Conditions in Michigan are quite different from those in the corn belt, where earliness in oats is desirable in order to enable them to ripen before hot summer weather. Our spring is often late, but when it opens everything comes with a rush, the hot spell usually striking us about July 1 and lasting two or three weeks. This hot weather injures the early oats. The oat that yields best with us is one that is not far enough advanced at this time to be hurt by hot weather and which heads out and ripens early in August immediately after the hot spell.
>
> Early oats should be of advantage in the Upper Peninsula of Michigan, because the season there starts late and rains in August are frequent, interfering with the harvesting of the later varieties. The Sixty-Day and Kherson are very unpopular, however, because farmers do not like the small, slender kernels.

Results in Wisconsin.

The results of varietal tests, including the Kherson and Sixty-Day oats, are reported for the years 1905 to 1907, inclusive, by the Wisconsin Agricultural Experiment Station (29). Since 1907 no tabulated results on varietal tests with oats have been reported. The annual and average yields of the Kherson and Sixty-Day and of three other varieties of oats grown at the Wisconsin Agricultural Experiment Station during the three years from 1905 to 1907, inclusive, are shown in Table VIII.

TABLE VIII.—*Annual and average yields of the Kherson, Sixty-Day, and three other varieties of oats grown at the Wisconsin Agricultural Experiment Station (at Madison) during two or more years in the 3-year period from 1905 to 1907, inclusive.*

Group and variety.	Wisconsin No.	Yield per acre (bushels).				
		1905	1906	1907	Average.	
					1906 and 1907.	1905 to 1907.
Early yellow:						
Sixty-Day	[1] 41	66.8	78.1	28.0	53.1	57.9
Kherson	49	....	60.0	33.7	46.9	....
Midseason white:						
Wisconsin Wonder	34	60.0	43.1	20.0	31.6	41.0
Swedish Select	[2] 4	50.0	39.0	12.5	25.8	33.8
Late white (side):						
White Russian	48	51.2	23.8	17.5	20.7	30.8

[1] Seed and Plant Introduction No. 12303 and Cereal Investigations No. 165.

[2] Seed and Plant Introduction No. 2788 and Cereal Investigations No. 134.

The data presented in Table VIII indicate that the early yellow varieties, Kherson and Sixty-Day, yielded well at Madison during the three years from 1905 to 1907, inclusive. In this period the Sixty-Day outyielded the Wisconsin Wonder, one of the leading midseason varieties, by about 17 bushels. This is much more than the normal difference between these varieties, however. The principal objection to the Sixty-Day and the Kherson oats at the Wisconsin station has been their rather weak straw and consequent liability to lodge. They are best adapted to the low and more fertile soils in the southern portion of the State, where they usually ripen in sufficient time to escape the most severe attacks of rust.

No report on experiments with oats has been published by the Wisconsin station since 1908, but in a letter dated December 5, 1917, Mr. B. D. Leith, assistant professor of agronomy at the University of Wisconsin, writes:

> We consider the Kherson oats particularly valuable under certain conditions. As a rule, we do not get as much lodging and rust, quite largely due to its earlier maturity. If it does lodge it fills out better than the Swedish Select when it lodges.
>
> Under adverse conditions it has been the highest yielding oat in our test plats. In 1915 it was harvested before our heavy storms lodged the other oats, and the yields ran above 100 bushels to the acre. In 1917 the yield was one of the best, largely due to the fact that it was not lodged so badly as the other oats, and there was less grain lost in harvesting. In very hot, dry years where oats are usually light the Kherson has been one of our best yielders.
>
> We have experimented with both Sixty-Day and Kherson oats. We pedigreed a strain from each and the pedigreed No. 7 selection from the Kherson strain proved a slightly heavier yielder and a little larger kernel than the pedigreed No. 6 from the Sixty-Day strain, so we disseminated the pedigreed No. 7 to the farmers and did not disseminate the pedigreed No. 6.
>
> Farmers in the sandy regions report that they are well pleased with the pedigreed No. 7 oats. It seems to be better suited to these regions than the midseason oats. I have in my hand a letter from a farmer on clay-loam soil who reports a yield of 80 bushels per acre from the pedigreed No. 7 oats last season. He states that it lodged considerably and if he had been able to save all the crop he feels sure that he would have received 100 bushels per acre. The real objection to this oats is that it can not command as high a price on the market as other oats. This man states that he will be obliged to take 3 cents a bushel less than he would for white oats.

Results in Illinois.

The Sixty-Day oat has been included in the varietal experiments at the Illinois station at Urbana (7) since 1905. This variety was also grown at De Kalb, in northern Illinois, during the four years from 1911 to 1914, inclusive, and at Fairfield, in southern Illinois, for several years. The Richland (Iowa No. 105), a yellow selection from the Kherson, was added to the tests at Urbana and De Kalb in 1915. The following year the Albion (Iowa No. 103), a white selection from the Kherson, was also grown at these two points.

RESULTS AT DE KALB.

The annual and average yields of the Sixty-Day, of two selections from the Kherson variety (Iowa No. 103 and Iowa No. 105), and of four other varieties of oats grown at De Kalb by the Illinois Agricultural Experiment Station in one or more years in the 10-year period from 1907 to 1916, inclusive, are shown in Table IX.

TABLE IX.—*Annual and average yields of three early and four midseason varieties of oats grown by the Illinois Agricultural Experiment Station (at De Kalb) during one or more years in the 10-year period from 1907 to 1916, inclusive.*

[Data compiled from Illinois Agricultural Experiment Station Bulletin 195 (7).]

Group and variety.	Yield per acre (bushels).										
										Average.	
	1907	1909	1910	1911	1912	1913	1914	1915	1916	1911 to 1914	1915 and 1916
Early yellow:											
Sixty-Day	37.8	......	......	57.7	62.2	41.1	55.7	......	......	54.2	......
Albion (Iowa No. 103, white)	......	......	......	......	......	......	......	67.6	69.6	......	68.6
Richland (Iowa No. 105)	......	......	......	......	......	......	......	......	60.7	......	......
Midseason white:											
American Banner	28.8	......	......	57.1	77.9	61.5	43.3	61.6	65.4	60.0	63.5
Schoenen	26.6	......	......	55.7	77.2	64.9	47.2	63.8	71.1	61.3	67.5
Silvermine	32.2	......	......	53.6	76.4	63.8	49.0	78.4	62.6	60.7	70.5
Swedish Select	......	52.9	78.4	50.6	70.0	48.0	47.5	62.8	59.3	54.0	61.1

The data shown in Table IX indicate that for northern Illinois the best midseason white varieties will outyield the early sorts. However, in 1915 and 1916 the Albion (Iowa No. 103), a white selection of the Kherson, has yielded nearly as well as the Silvermine and the Schoenen, the two leading midseason white varieties. This new oat appears to be of considerable promise for northern Illinois.

RESULTS AT URBANA.

The annual and average yields of four strains of early yellow and six other varieties of oats grown at the Illinois Agricultural Experiment Station at Urbana in one or more years during the 12-year period from 1905 to 1916, inclusive, are presented in Table X.

The data given in Table X show that in central Illinois the early varieties outyield all others and are therefore to be recommended. So far the original Sixty-Day has outyielded the Richland (Iowa No. 103), a yellow selection from Kherson. The Albion (Iowa No. 105), however, a white selection from the Kherson, materially outyielded both the Kherson and the Sixty-Day in 1916, the first year it was grown at Urbana. Both these pure lines of Kherson appear to be well worth growing in central Illinois.

TABLE X.—*Annual and average yields of four early yellow and six other varieties of oats grown at the Illinois Agricultural Experiment Station (at Urbana) in one or more of the 11 years, 1905 and 1907 to 1916, inclusive.*

[Data compiled from Illinois Agricultural Experiment Station Bulletin 195 (7).]

Group and variety.	Yield per acre (bushels).													
	1905	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	Average.		
												1905 and 1907 to 1916	1913 to 1916	1915 and 1916
Early yellow:														
Sixty-Day	56.9	67.1	48.8	46.6	75.6	49.1	72.4	28.4	51.0	83.6	59.2	58.1	55.6	71.4
Kherson	.....	.....	.....	.....	.....	.....	.....	32.3	41.3	66.9	65.4	.....	51.5	66.2
Richland (Iowa No. 105)	.....	.....	.....	.....	.....	.....	.....	.....	.....	70.4	67.5	.....	.....	69.0
Albion (Iowa No. 103, white)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	76.4	.....	.....	.....
Early white:														
Early Champion	.....	.....	.....	.....	.....	.....	.....	24.3	41.6	66.6	57.8	.....	47.6	62.2
Midseason white:														
Siberian	68.2	33.7	31.7	43.6	58.6	60.5	72.8	24.3	50.4	62.3	71.4	52.5	52.1	66.9
American Banner	56.7	34.7	25.3	46.6	56.2	48.5	63.7	32.8	54.2	65.9	70.5	50.5	55.9	68.2
Swedish Select	.....	.....	.....	.....	.....	58.3	70.8	14.1	54.5	61.6	68.5	.....	49.7	65.1
Late white (side):														
Silver Plume	.....	.....	.....	.....	.....	.....	79.8	20.8	53.2	67.5	64.2	.....	51.4	65.9
Late black (side):														
Black Tartarian	.....	30.9	16.9	43.7	.....	.....	.....	.....	.....	60.3	52.9	.....	.....	56.6

RESULTS AT FAIRFIELD.

The annual and average yields of one representative each of the early yellow, early white, midseason white, and early red groups, respectively, grown by the Illinois Agricultural Experiment Station at Fairfield in 1909 and 1915, are given in Table XI, together with the yield of the Richland in 1915.

TABLE XI.—*Annual and average yields of the Sixty-Day, Richland, and three other varieties of oats grown by the Illinois Agricultural Experiment Station (at Fairfield) in the years 1909 and 1915.*

[Data compiled from Illinois Agricultural Experiment Station Bulletin 195 (7).]

Group and variety.	Yield per acre (bushels).			Group and variety.	Yield per acre (bushels).		
	1909	1915	Average.		1909	1915	Average.
Early yellow:				Early red:			
Sixty-Day	50.1	24.5	37.3	Red Rustproof (Texas Red)	60.1	34.1	47.1
Richland (Iowa No. 105)	......	30.6	......	Midseason white:			
Early white:				White Bonanza	35.4	34.5	35.0
Early Champion	48.9	27.3	38.1				

The few data given in Table XI show that the early red variety Red Rustproof (Texas Red), outyielded all others in the 2-year test at Fairfield, where it exceeded the Sixty-Day by about 10 bushels in average yield.

Conclusions.

The average yield of the leading variety in each group at the stations included in the east North-Central States is shown graphically in figure 4.

The data presented in Table VI indicate that under Ohio conditions early oats will yield about as well as the best midseason white varieties, such as Siberian, Big Four, Improved American, and Silvermine, and that where early maturity is an advantage they are preferable to these varieties. The late white side varieties are not to be recommended.

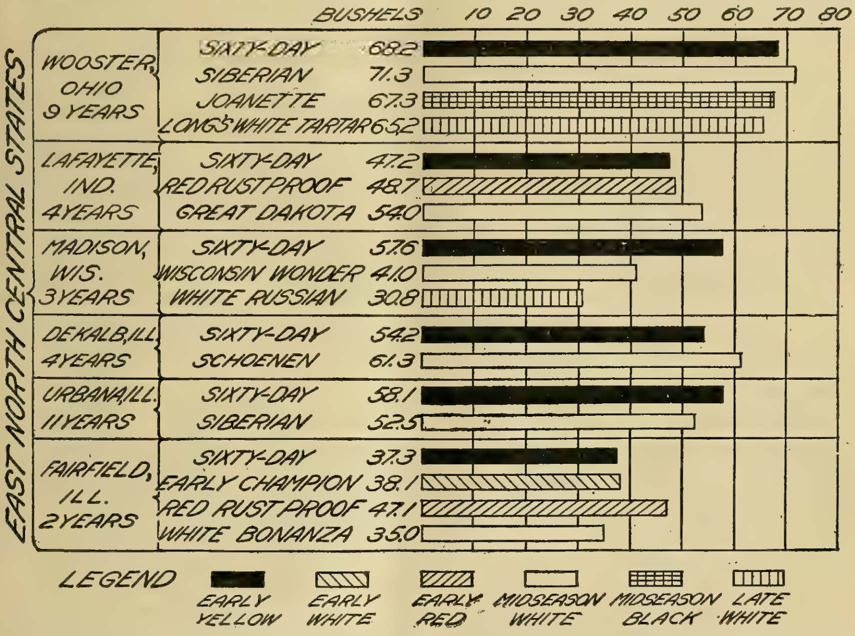

FIG. 4.—Diagram showing the average yields, in bushels per acre, of the highest yielding variety of each of several groups of oats at six agricultural experiment stations in the east North-Central States, during the periods of years indicated.

The results obtained at La Fayette, Ind., show that the Kherson and the Sixty-Day are not desirable for growing in that State. The midseason white varieties apparently are the best under Indiana conditions. The midseason varieties are preferable to the early yellow varieties, Kherson and Sixty-Day, for the greater portion of Michigan.

The available Wisconsin data happen to include results for two years which were particularly unfavorable to midseason and late oats. They serve to show, however, that early oats are well worth growing on a part of the acreage in that State, particularly in the southern half.

Conditions in northern Illinois (De Kalb) are quite similar to those at Madison, Wis., but the data include those for several years favorable to midseason varieties, so that on the average these have outyielded the Sixty-Day. The yields of the Sixty-Day in the less favorable years with correspondingly higher prices, and particularly the high yields of the two Kherson selections from Iowa, indicate that early oats are desirable in this section.

In central Illinois the Sixty-Day has considerably outyielded the midseason and late varieties in an 11-year test and can be strongly recommended. In southern Illinois, as indicated by the test at Fairfield, the Red Rustproof is to be preferred.

RESULTS IN THE WEST NORTH-CENTRAL SECTION.

The west north-central section includes the States of Minnesota, Iowa, and Missouri, and the eastern and more humid portions of the Dakotas, Nebraska, and Kansas. Varietal experiments including Kherson and Sixty-Day oats have been conducted in all these States either independently by the State agricultural experiment stations or in cooperation with the United States Department of Agriculture.

The Minnesota station has grown the Kherson and Sixty-Day oats since 1906, but has not published the results of its experiments since 1908. The Northwest Experiment Station at Crookston, however, has recently reported the results of varietal trials, including these varieties, during the five years from 1912 to 1916. The North-Central Experiment Station at Grand Rapids also has reported the results of varietal experiments with Kherson and Sixty-Day oats for 1915 and 1916. The data available from eastern North Dakota are for the years from 1901 to 1908, and from South Dakota for the years from 1904 to 1917. Results are available from the Iowa station for the 11 years from 1907 to 1917, inclusive. Nebraska has recently published data on varietal experiments with oats, so that figures are available for the 14 years from 1903 to 1916. The Kansas station has published results obtained during the 7-year period from 1903 to 1909. The data since 1910 have been obtained in cooperation with the United States Department of Agriculture. No reports of varietal trials of oats at the Missouri station have been published for many years.

Results in Minnesota.

RESULTS AT UNIVERSITY FARM.

The annual and average yields of the Kherson, Sixty-Day, and six other commercial varieties of oats grown at the Minnesota Agricultural Experiment Station, University Farm, St. Paul (5), during the 3-year period 1906 to 1908, inclusive, are presented in Table XII.

The few data given in Table XII are not very conclusive. The Sixty-Day variety apparently has decidedly outyielded the Kherson, but the difference is due to an unexplained wide variation in yields in 1906. The best midseason white varieties, Myrick Banner and Lincoln, have yielded slightly less than the Sixty-Day. Typical panicles and spikelets of three leading midseason white varieties of oats are shown in figure 5.

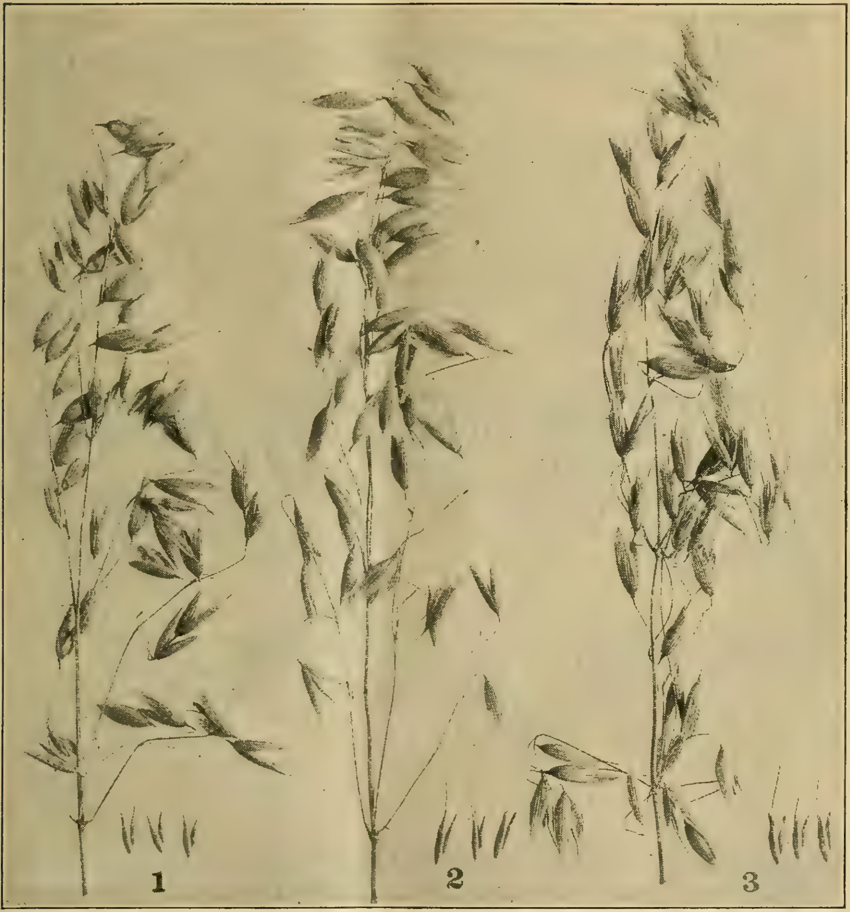

FIG. 5.—Panicles and spikelets of three midseason white varieties of oats: 1, Victory; 2, Silvermine; 3, Swedish Select.

In a letter dated December 20, 1917, Prof. A. C. Arny, agronomist of the Minnesota station, states that in an experiment with heavy, medium, and light seed in which Ligowo and Sixty-Day (Minn. No. 261) were used, the Sixty-Day consistently outyielded the Ligowo in all cases in 1914, 1915, and 1916, but that the yields were reversed in 1917. He further states that the Victory oat has been the leading variety at the Minnesota station in recent years, and that a selection from Sixty-Day has ranked second to Victory for three years. In his opinion early oats of the Sixty-Day type are promising in southern Minnesota.

TABLE XII.—*Annual and average yields of the Kherson, Sixty-Day, and six other varieties of oats grown at the Minnesota Agricultural Experiment Station (at St. Paul) during the 3-year period from 1906 to 1908, inclusive.*

[Data compiled from Minnesota Agricultural Experiment Station Bulletin 115 (5).]

Group and variety.	Minnesota No.	Yield per acre (bushels).			
		1906	1907	1908	Average.
Early yellow:					
Sixty-Day	261	76.8	62.5	44.0	61.1
Kherson	358	36.2	77.5	42.0	51.9
Early white:					
Early Champion	267	63.7	65.6		
Midseason white:					
Myrick Banner	348	89.3	46.8	45.3	60.5
American Banner	311	88.1	36.9	40.7	55.2
Big Four	353	71.8	50.6	32.5	51.6
Lincoln	282	76.8	48.1	49.0	58.0
Late white (side):					
White Russian	302	85.0	38.7	33.5	52.4

RESULTS AT CROOKSTON.

The University of Minnesota Department of Agriculture has included the Kherson and Sixty-Day oats in the varietal experiments at the Northwest Experiment Station at Crookston since 1912. The data from these experiments have been published for the five years from 1912 to 1916, inclusive (34, pp. 38-40). The annual and average yields of the most important varieties are shown in Table XIII.

TABLE XIII.—*Annual and average yields of three strains of early yellow and twelve other varieties of oats grown at the Northwest Experiment Station, Crookston, Minn., during three or more years in the 5-year period from 1912 to 1916, inclusive.*

[Data compiled from Report of the Superintendent, Northwest Experiment Station, 1910–1916 (34, pp. 38–40).]

Group and variety.	Yield per acre (bushels).					
	1912	1913	1914	1915	1916	Average.
Early yellow:						
Sixty-Day	60.2	60.5	46.3	63.4	35.5	53.2
Do		32.1	32.2	47.2		
Kherson	40.1	39.5	47.7	65.4	34.2	45.4
Early white:						
Early Champion	45.1	31.8	46.3	42.9	27.6	38.7
Midseason yellow:						
Golden Beauty	62.0	57.0	47.5	99.6	21.7	55.6
Midseason white:						
King Oscar	58.1	53.2	60.6	89.2	26.1	57.4
Banner	81.8	56.8	45.0	72.8	28.6	57.0
Improved American	59.3	59.0	50.9	91.7	22.2	56.6
Canadian, No. 429	68.0	59.5	44.1	89.6	20.4	56.3
Victory	51.3	54.5	56.9	85.6	30.2	55.7
Danish Island	34.3	73.7	60.1	79.8	24.5	54.5
Lincoln, No. 282	50.3	47.4	55.0	94.2	23.3	54.0
Swedish Select	64.1	51.3	47.2	76.3	24.5	52.7
Late white (side):						
Canadian Cluster	55.1	55.7	41.3	86.5	20.0	51.7
White Russian	60.1	43.1	48.4	88.8	23.6	52.8

The data contained in Table XIII show that on the average the midseason white varieties have slightly outyielded the Sixty-Day in northwestern Minnesota, the better varieties averaging about 4 bushels more in the 5-year period from 1912 to 1916. In occasional unfavorable years, as in 1916, the early oats considerably outyielded the midseason varieties. The 5-year average yields of the Sixty-Day and the White Russian, a late side oat popular in this section, were practically the same. The Sixty-Day averaged about 8 bushels more than the Kherson for the 5-year period, but the difference is due entirely to wide variations in the yields in 1912 and 1913.

RESULTS AT GRAND RAPIDS.

The University of Minnesota Department of Agriculture has included the Kherson and Sixty-Day oats in the varietal experiments conducted at the North-Central Experiment Station at Grand Rapids (26, p. 16). The results of these experiments are reported for the years 1915 and 1916. The annual and average yields of the Sixty-Day and Kherson and a number of other varieties are shown in Table XIV.

Table XIV.—*Annual and average yields of the Kherson, the Sixty-Day, and eight other varieties of oats grown at the North-Central Experiment Station, Grand Rapids, Minn., in 1915 and 1916.*

[Data compiled from Report of Progress of Work and Guide to Experimental Plats, North-Central Experiment Station, Minnesota Agricultural Experiment Station, 1917 (26, p. 16).]

Group and variety.	Yield per acre (bushels).			Group and variety.	Yield per acre (bushels).		
	1915	1916	Average.		1915	1916	Average.
Early yellow:				Midseason white—Continued.			
Kherson	106.3	61.9	84.1	Lincoln (pedigreed)	95.6	46.6	71.1
Sixty-Day	110.6	40.0	75.3	Danish Island	84.4	56.9	70.7
Midseason yellow:				Abundance	83.9	52.2	68.1
Golden Beauty	86.8	57.5	72.2	Swedish Select	79.6	50.6	65.1
Midseason white:				Late white (side):			
Banner	97.9	61.2	79.6	White Russian	100.0	57.8	78.9
Newmarket	88.6	57.5	73.1				

The data presented in Table XIV show that in 1915 the Kherson and Sixty-Day decidedly outyielded all other varieties at Grand Rapids. In 1916 occurred an unexplained wide difference in yield between them, the Kherson being the highest yielding and the Sixty-Day the lowest of the 12 varieties included in the tests. Evidently the Sixty-Day was grown under very unfavorable conditions or some discrepancy occurred in the experiments which resulted in the abnormally low yield. The average yield of the Kherson for the two years is 4.5 bushels higher than that of any other variety.

Results in Eastern North Dakota (35).[1]

The annual and average yields of the two early yellow varieties, Sixty-Day and Seventy-five Day, and of eight other varieties of oats grown at the North Dakota Agricultural Experiment Station at Fargo during six or more years of the 8-year period from 1901 to 1908, inclusive, are shown in Table XV. These results were obtained in cooperation with the Office of Cereal Investigations.

TABLE XV.—*Annual and average yields of two early yellow and eight other varieties of oats grown at the North Dakota Agricultural Experiment Station (at Fargo) during six or more years in the 8-year period from 1901 to 1908, inclusive.*

[Data obtained cooperatively by the North Dakota Agricultural Experiment Station and the Bureau of Plant Industry.]

Group and variety.	North Dakota No.	Yield per acre (bushels).							Average.	
		1901	1902	1903	1904	1906	1907	1908	1901 to 1904 and 1906 to 1908	1902 to 1904 and 1906 to 1908
Early yellow:										
Sixty-Day	666	50.4	72.2	42.0	59.2	47.9	77.5	95.2	63.5	65.7
Seventy-five Day[1]	617	......	96.9	50.7	75.4	54.2	76.5	91.5	......	74.2
Midseason white:										
Big Four	725	58.8	41.6	70.5	54.9	58.1	60.0	75.0	59.8	60.0
Abundance	866	58.9	47.5	71.2	67.3	50.0	54.2	66.5	59.4	59.5
Siberian	864	60.5	47.0	69.1	55.5	47.9	55.5	80.0	59.4	59.2
Lincoln	768	54.5	33.9	66.1	65.5	43.7	55.0	95.0	59.1	59.9
Swedish Select	1139	......	30.8	68.2	54.6	48.1	58.7	67.0	......	54.6
Late white (side):										
Tartarian[2]	388	43.9	63.9	77.3	58.7	55.6	51.0	75.0	60.8	63.6
New Zealand	868	49.9	49.3	66.3	65.9	52.5	44.0	82.5	58.6	60.1
White Russian	238	......	55.8	74.9	59.0	55.5	35.2	84.0	......	60.7

[1] S. P. I. No. 5168, similar to Sixty-Day.

[2] Probably the same as White Russian.

The data in Table XV show that the early yellow varieties of the Sixty-Day group considerably outyielded all others at Fargo in the seven years for which data are available, the Sixty-Day exceeding the Big Four, the best of the midseason varieties, by 3.7 bushels, and the Tartarian, a late side oat, by 2.7 bushels. While these differences are not large enough to be regarded as significant, the yields indicate that in this section of the Red River Valley the early oats are at least as good as the midseason and late varieties. The so-called "Seventy-five Day" oat, an earlier importation from Russia, probably identical with the Sixty-Day, has outyielded the latter at Fargo by 8.5 bushels in a 6-year period.

Under date of December 7, 1917, Prof. R. C. Doneghue, agronomist of the North Dakota station, writes:

> It is my opinion, based on the trials here at Fargo, that the Sixty-Day oats are very well suited to the Red River Valley. They stand up very well, yield well and will

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[1] Data for 1907 and 1908, from unpublished annual reports of Prof. J. H. Shepperd and Mr. O. O. Churchill, formerly collaborator and special agent, respectively, filed in the Office of Cereal Investigations.

give fairly good results in quite a wide range of seasons. I consider them one of the best varieties for this region. From the standpoint of distributing the harvest season over a longer period it might be wise to grow some of the midseason varieties as well as the Sixty-Day oats on the farms of the Red River Valley, but I think that Sixty-Day or Kherson can be grown on a very large percentage of the farms with profit.

Results in Eastern South Dakota.[1]

The annual and average yields of the Sixty-Day and six other varieties of oats grown by the South Dakota Agricultural Experiment Station in cooperation with the United States Department of Agriculture at Brookings are given in Table XVI. Data are available for the 14 years from 1904 to 1917, inclusive.

Table XVI.—*Annual and average yields of the Sixty-Day and six other varieties of oats grown at the South Dakota Agricultural Experiment Station (at Brookings) during seven or more years in the 14-year period from 1904 to 1917, inclusive.*

[Data obtained in cooperation with the South Dakota Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).														
		1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Average, 1904 to 1913
Early yellow:																
Sixty-Day	165	69.6	80.0	61.6	24.4	59.2	46.7	28.7	19.4	64.0	90.0	51.6	84.3	73.0	60.2	54.4
Midseason white:																
Swedish Select	134	70.0	45.3	61.6	24.1	25.0	44.0	29.0	4.7	86.0	91.9	42.4	48.4	37.0	51.6	48.2
Belyak	336	[1]128.0	37.5	42.8	9.1	26.8	28.9	27.8	2.0	86.5	97.5	40.6	(2)	....	....	38.7
Banner	160	54.7	35.2	42.7	8.1	2.5	22.2	30.0	3.6	98.1	99.4	46.9	(2)	....	....	39.7
Midseason black:																
North Finnish Black	174	65.0	35.7	40.8	5.0	20.6	28.6	28.4	10.9	73.1	71.5	....	....	....	....	38.0
Late white (side):																
Wideawake[3]	154	51.7	24.1	35.0	11.9	12.5	29.7	25.3	0.9	....	94.0	56.2	(2)	....	....	......
White Tartar	445	....	41.9	32.3	6.3	10.4	25.8	26.6	1.9	....	....	....	....	....	....	......

[1] Not comparable; grown under unfavorable conditions.
[2] Destroyed by hail.
[3] The variety is incorrectly named, as the true Wideawake is not a side oat.

The data presented in Table XVI show that the early yellow variety Sixty-Day has outclassed all other varieties at Brookings. Its nearest competitor has been the Swedish Select, but the 14-year average yield of this variety has fallen 10 bushels below that of the Sixty-Day, the average yields being 58.1 and 47.9 bushels, respectively. The Banner, a popular old variety, has been exceeded in yield by the Sixty-Day in seven of the eleven years in which both were grown. In seven years (1905–1911) the average yield of the Sixty-Day (45.7 bushels) was more than double that of the White Tartar (20.7 bushels), a late side oat.

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[1] Data obtained cooperatively by the South Dakota station and the Bureau of Plant Industry. The data previous to 1912 were published by the United States Department of Agriculture (10).

Results in Iowa.[1]

The annual and average yields of five strains of early yellow and thirteen other varieties of oats grown at the Iowa Agricultural Experiment Station at Ames in cooperation with the United States Department of Agriculture during three or more years in the 11-year period from 1907 to 1917, inclusive, are presented in Table XVII.

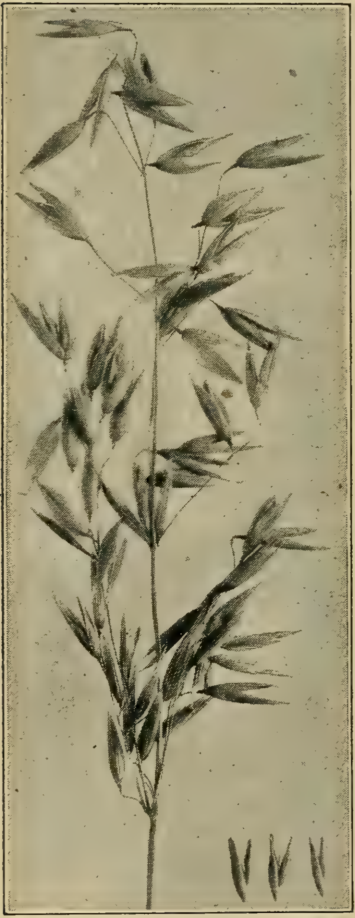

FIG. 6.—Panicle and spikelets of an early white variety of oats, Early Champion.

The data presented in Table XVII indicate that the early yellow varieties, Kherson, Sixty-Day, and selections from them, are the most dependable for Iowa conditions. The average yield of the original Kherson in the 11-year period from 1907 to 1917, inclusive, is 52.9 bushels, as compared with similar averages of 52.4 and 52.2 bushels for Myrick and Silvermine, respectively, the two highest yielding midseason varieties. However, since 1911 Richland, a selection from Kherson, has consistently outyielded all others. In the 7-year period from 1911 to 1916, inclusive, this selection has exceeded the original Kherson by 4.8 bushels, and the Silvermine, its nearest competitor of the midseason varieties, by 2.9 bushels in average yield per acre. Albion, a white selection from Kherson, has not been as promising at Ames under central Iowa conditions, but is much more popular with farmers. A panicle and spikelets of Early Champion, an early white oat, are shown in figure 6.

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[1] Data obtained cooperatively by the Iowa Agricultural Experiment Station and the Bureau of Plant Industry. Data for 1907 published in Iowa Agr. Exp. Sta. Bul. 96, entitled "Oats, Varieties, Seed, Smut, Seedbed, Seeding," by M. L. Bowman and L. C. Burnett, 1908; for 1908 to 1910, inclusive, published in Iowa Agr. Exp. Sta. Bul. 128, entitled "Some Data for Oat Growers," by L. C. Burnett, 1912; for 1911 and succeeding years, compiled from unpublished annual reports of L. C. Burnett, agent, to the Office of Cereal Investigations.

TABLE XVII.—*Annual and average yields of the Kherson, the Albion, the Richland, two strains of the Sixty-Day, and thirteen other varieties of oats grown at the Iowa Agricultural Experiment Station (at Ames) during three or more years in the 11-year period from 1907 to 1917, inclusive.*

[Data obtained in cooperation with the Iowa Agricultural Experiment Station.]

Group and variety.	Yield per acre (bushels).												
	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Average.	
												1907 to 1917	1911 to 1917
Early yellow:													
Kherson	45.6	48.8	35.3	62.2	38.1	65.6	62.8	55.3	49.1	53.8	65.0	52.9	55.7
Albion (Iowa No. 103, white)	.....	.....	.....	.....	40.6	53.7	63.7	55.6	41.6	46.1	73.7	.....	53.6
Richland (Iowa No. 105)	.....	.....	.....	.....	44.8	83.7	55.6	62.8	59.3	53.6	63.7	.....	60.5
Sixty-Day	.....	50.0	31.2	67.8	.....	.....	.....	.....	.....	.....	.....	.....	.....
Do	.....	45.2	50.0	57.8	.....	.....	.....	.....	.....	.....	.....	.....	.....
Early white:													
Early Champion	29.3	37.5	24.7	61.9	35.0	48.1	50.6	48.4	42.2	48.7	68.1	45.0	48.7
Daubeney	.....	.....	38.1	53.7	31.0	71.2	50.3	48.1	50.9	52.4	81.9	.....	55.1
Early red:													
Burt	.....	.....	.....	43.8	40.6	60.6	52.1	45.6	54.7	55.3	79.4	.....	55.5
Red Rustproof (Texas Red)	35.8	41.9	32.8	66.6	5.9	68.7	49.1	44.7	54.4	51.2	66.2	47.0	48.6
Midseason yellow:													
Probsteier	19.3	28.1	27.5	61.9	25.5	56.9	51.2	40.3	53.1	51.5	65.6	43.7	49.2
Midseason white:													
Myrick	26.2	38.1	32.5	91.9	31.1	91.9	57.5	44.1	61.8	37.7	63.1	52.4	55.3
Silvermine	31.5	36.6	31.6	70.6	36.3	81.9	60.3	46.8	55.2	51.7	71.2	52.2	57.6
Green Russian	36.2	39.4	33.4	64.1	31.8	83.7	53.4	45.7	57.6	53.6	50.0	49.9	53.7
Irish Victor	28.0	33.8	33.4	66.2	37.4	79.4	57.2	43.8	54.3	46.7	65.6	49.6	54.9
Early Gothland	25.0	33.7	35.9	70.6	23.6	80.0	62.8	43.1	60.7	50.0	53.7	49.0	53.4
Siberian	29.2	36.6	31.9	59.4	20.5	88.1	59.4	40.0	59.8	52.1	53.7	48.2	53.4
Swedish Select	32.0	31.0	33.1	62.2	25.5	75.0	50.6	37.6	44.8	43.0	63.7	45.3	48.6
Midseason black:													
Joanette	35.6	28.4	33.1	60.3	23.9	88.7	50.2	43.7	60.6	52.6	66.9	49.5	55.2
Late white (side):													
White Russian	27.1	25.6	45.6	60.0	19.8	83.1	46.6	44.4	52.3	41.4	35.0	43.7	46.1

Results in Nebraska.

The annual and average yields of the Kherson, the Sixty-Day, and seven other varieties of oats grown at the Nebraska Agricultural Experiment Station at Lincoln (21 and 27) during six or more years in the 14-year period from 1903 to 1916, inclusive, are given in Table XVIII.

The data in Table XVIII show that the early red varieties have decidedly outyielded both the early yellow and midseason white varieties at Lincoln. In the 12-year period from 1905 to 1916, inclusive, the Kherson has fallen 7.4 bushels below the Burt and 5.8 bushels below the Red Rustproof (Texas Red) in average yield per acre. In this period the Swedish Select has yielded 3.5 bushels less than the Kherson and 10.9 bushels less than the Burt. The data show conclusively that the Kherson is better than the midseason varieties in eastern Nebraska where the conditions are similar to those at Lincoln, but that the Red Rustproof and Burt are superior to it.

TABLE XVIII.—*Annual and average yields of the Kherson, the Sixty-Day, and seven other varieties of oats grown at the Nebraska Agricultural Experiment Station (at Lincoln) during six or more years in the 14-year period from 1903 to 1916, inclusive.*

[Data compiled from Nebraska Agricultural Experiment Station Bulletin No. 160 (21).]

Group and variety.	Yield per acre (bushels).																
	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	Average.		
															1903 to 1916	1905 to 1916	1911 to 1916
Early yellow:																	
Kherson	68.0	55.1	82.7	36.4	49.0	54.0	67.2	41.7	38.5	37.4	44.8	69.7	40.1	85.4	55.0	53.9	52.7
Sixty-Day	52.4	51.8	84.2	40.7	59.6	....	60.3	....	....	....	....	....	....	....	....	....	....
Early red:																	
Red Rustproof (Texas Red)	57.5	40.6	81.7	44.1	42.5	65.0	77.6	53.1	42.5	35.6	60.3	71.3	56.0	87.1	58.2	59.7	58.8
Burt	....	....	85.5	42.3	48.5	64.3	74.1	60.7	38.2	38.6	61.4	76.7	65.9	79.2	....	61.3	60.0
Burt (June)	....	....	....	....	....	....	....	....	32.0	33.9	53.3	63.9	54.9	85.5	....	....	53.9
Midseason white:																	
Swedish Select	31.5	24.5	69.2	42.8	32.5	44.0	67.1	55.8	41.2	26.4	45.9	60.7	35.2	83.6	47.2	50.4	48.8
American Banner	45.6	31.8	76.3	40.2	31.0	34.3	61.7	51.9	35.7	28.0	33.9	47.1	34.5	67.5	44.3	45.2	41.1
Lincoln	....	22.8	85.2	42.3	28.5	43.6	71.6	51.8	39.1	29.5	40.3	53.5	30.7	70.3	....	48.9	43.9
University No. 6 (Improved Ligowo)	....	31.5	77.1	34.6	29.4	49.0	68.0	45.2	32.6	25.9	22.0	49.1	31.0	66.3	....	44.2	37.8

Results in Eastern Kansas.

The annual and average yields of seven early yellow and five other varieties of oats grown at the Kansas Agricultural Experiment Station at Manhattan during five or more years in the 10-year period from 1908 to 1917, inclusive, are shown in Table XIX.

TABLE XIX.—*Annual and average yields of seven early yellow and five other varieties of oats grown at the Kansas Agricultural Experiment Station (at Manhattan) during five or more years in the 10-year period from 1908 to 1917, inclusive.*[1]

[Data obtained in cooperation with the Kansas Agricultural Experiment Station.]

Group and variety.	Kansas No.	Yield per acre (bushels).												
		1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Average.		
												1908 to 1917	1908 and 1909, 1911 to 1917.	1911 to 1917
Early yellow:														
Kherson	5034	28.1	60.5	55.4	18.0	45.5	13.2	27.1	40.2	50.8	47.8	38.7	36.8	34.7
Do	6021	....	....	48.5	18.2	41.3	16.9	34.5	45.0	51.7	50.6	....	....	36.9
Sixty-Day (Sel. 5009)	6014	....	....	....	17.9	49.7	5.8	24.2	42.2	....	....	....	....	....
Sixty-Day (Kans.)	5009	23.6	69.7	54.5	14.4	52.6	11.7	29.1	37.8	51.9	51.7	39.7	38.1	35.6
Sixty-Day (Ind.)[2]	5043	....	85.8	62.8	18.2	54.3	10.4	26.2	27.5	47.9	....	....	....	....
Sixty-Day (N. Dak.)[2]	5044	....	88.5	59.3	15.7	45.4	11.2	31.9	23.1	48.3	....	....	....	....
Seventy-five Day	5104	....	58.9	....	23.9	42.2	13.7	30.7	40.4	....	....	....	....	....
Early red:														
Burt (C. I. No. 293)	5020	41.9	64.9	....	18.0	45.3	12.9	32.7	46.3	56.1	61.5	....	42.2	39.0
Red Rustproof (Texas Red)	5031	45.8	43.0	....	17.2	63.2	10.4	18.1	33.9	42.0	49.5	....	35.9	33.5
Do	5015	37.5	63.7	....	14.1	56.8	16.1	40.3	38.4	53.5	57.6	....	42.0	39.5
Red Algerian	5105	....	56.2	....	17.7	59.6	18.3	34.7	38.7	60.6	56.6	....	....	40.9
Midseason white:														
Green Russian	5122	....	....	57.5	16.4	57.1	6.3	32.6	37.3	44.4	52.7	....	....	35.3

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[1] Data from unpublished annual reports of Prof. W. M. Jardine, formerly collaborator, to the Office of Cereal Investigations.

[2] Data from trilocal experiments.

The data in Table XIX show that for eastern Kansas the Kherson and Sixty-Day are close competitors of the Burt, Red Rustproof, and other early red varieties. In the nine years, 1908, 1909, and 1911 to 1917, inclusive, the average yield of the Sixty-Day was 38.1 bushels and that of the Burt 42.2 bushels. In the 7-year period from 1911 to 1917, inclusive, the Kherson strain, Kansas No. 6021, has fallen about 4 bushels below the Red Algerian, but has outyielded the Green Russian, the only midseason white variety included in the tests, by about 1.5 bushels.

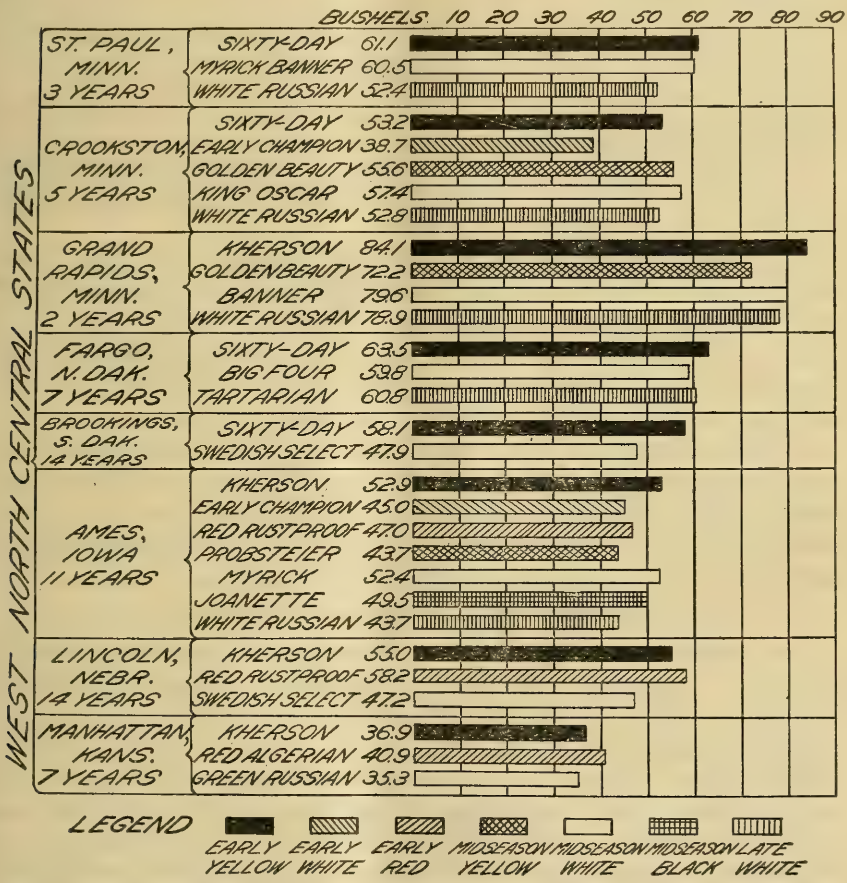

FIG. 7.—Diagram showing the average yields, in bushels per acre, of the highest yielding variety of each of several groups of oats at eight experiment stations in the west north-central section during the periods of years indicated.

Conclusions.

The average yield of the leading variety in each group at the stations included in the west north-central section is shown graphically in figure 7.

In general, Kherson and Sixty-Day oats have yielded as well as or slightly better than other varieties in this section.

At the agricultural experiment station at St. Paul, in eastern Minnesota, early varieties have yielded equally as well as the best midseason varieties. At the Crookston substation in northwestern Minnesota the midseason varieties have outyielded the early varieties, Kherson and Sixty-Day. White Russian, a late side oat, popular in this section, however, has not exceeded the early varieties in average yield at this station. Two years' results at the Grand Rapids substation in north-central Minnesota favor the early varieties, but additional data are necessary before more definite conclusions can be drawn.

Early varieties of the Sixty-Day type have slightly exceeded the leading midseason varieties in average yield per acre at the agricultural experiment station at Fargo in the Red River valley in southeastern North Dakota.

At the agricultural experiment station at Brookings, in eastern South Dakota, Sixty-Day oats have decidedly outyielded all others and are to be strongly recommended.

At the agricultural experiment station at Ames, in central Iowa, early varieties of the Kherson or Sixty-Day type have yielded better than the best midseason varieties. During the past seven years Richland, a short-strawed yellow oat, selected from Kherson, has consistently outyielded all others. Albion (Iowa No. 103), a white selection from the Kherson, is very popular in the State.

At the agricultural experiment stations at Lincoln, Nebr., and Manhattan, Kans., the early red varieties, Burt and Red Rustproof, have yielded considerably better than the Kherson and Sixty-Day. The early yellow varieties have outyielded the midseason varieties and are the next best to grow in eastern Nebraska and Kansas.

RESULTS IN THE LOWER MISSISSIPPI VALLEY.

The section here designated as the lower Mississippi Valley includes Kentucky, Tennessee, Mississippi, Louisiana, Arkansas, southern Missouri, southeastern Kansas, and the eastern or more humid portions of Oklahoma and Texas.

The spring oat crop in this section of the United States is not an important one, and consequently very little experimental work has been done with it. The State agricultural experiment stations of Tennessee, Arkansas, and Missouri have reported some varietal experiments with Kherson and Sixty-Day oats. In some cases, comparisons have been made with fall-sown varieties.

The Tennessee Agricultural Experiment Station at Knoxville grew the Kherson variety during the five years from 1908 to 1912, inclusive, in comparison with winter oats as well as with other spring varieties. During the four years, 1910 to 1913, inclusive, the Missouri Agricultural Experiment Station grew the Kherson and a number of other varieties near Carthage (Jasper County), in southwestern Missouri.

Varietal experiments including the Sixty-Day oat were conducted by the Arkansas station at Fayetteville during the 5-year period from 1909 to 1913, inclusive.

During the six years from 1904 to 1909, inclusive, the United States Department of Agriculture, in cooperation with the Kansas Agricultural Experiment Station, conducted varietal experiments with oats at McPherson, Kans. Several early yellow varieties were included in these experiments. No results of varietal experiments with oats have been published by the Oklahoma station. Three years' results of varietal experiments with oats have been reported by the Denton (Tex.) substation.

Results in Tennessee.

The annual and average yields of the Kherson and three other varieties of oats grown at the Tennessee Agricultural Experiment Station (28) during two or more years in the 5-year period from 1908 to 1912, inclusive, are presented in Table XX.

TABLE XX.—*Annual and average yields of the Kherson and three other varieties of oats grown at the Tennessee Agricultural Experiment Station (at Knoxville) during two or more years in the 5-year period from 1908 to 1912, inclusive.*

[Data compiled from Tennessee Agricultural Experiment Station Bulletin 112 (28).]

Group and variety.	Yield per acre (bushels).						
	1908	1909	1910	1911	1912	Average.	
						1911 and 1912	1908 to 1912
Early yellow:							
Kherson	29.5	26.4	43.2	12.6	44.3	28.5	31.2
Early red:							
Burt	27.3	20.2	45.6	14.9	47.7	31.3	31.1
Red Rustproof[1]	20.7	23.3	32.7	12.8	45.2	29.0	26.9
Winter:							
Culberson				21.1	50.8	36.0	

[1] This variety is grown from both spring and fall seeding in the South.

Table XX shows that in the 5-year period from 1908 to 1912, inclusive, the Kherson outyielded both the Burt and the Red Rustproof, though exceeding the Burt by only 0.1 bushel. However, in 1911 and 1912 the Culberson, a winter variety, decidedly outyielded all spring-sown oats. Additional data obtained with winter varieties in other years than those for which data are given in Table XX show that in general winter oats are superior to spring oats for growing in most sections of Tennessee.

Results in Southwestern Missouri.

The annual and average yields of the Kherson and five other varieties of oats grown near Carthage, Mo. (18), during the 4-year period from 1910 to 1913, inclusive, are shown in Table XXI.

TABLE XXI.—*Annual and average yields of the Kherson and five other varieties of oats grown near Carthage, Mo., by the Missouri Agricultural Experiment Station during the 4-year period from 1910 to 1913, inclusive.*

[Compiled from Missouri Agricultural Experiment Station Bulletin 123 (18).]

Group and variety.	Yield per acre (bushels).				
	1910	1911	1912	1913	Average.
Early yellow:					
Kherson	55.5	11.3	14.8	15.9	24.4
Early red:					
Red Rustproof (Texas Red)	57.5	11.3	17.5	11.7	24.5
Midseason white:					
Swedish Select	59.0	5.6	16.6	8.0	22.3
Lincoln	66.8	7.0	11.3	9.0	23.5
Midseason black:					
Victor	52.6	8.4	11.9	7.7	20.2
Late white (side):					
White Tartar	64.8	8.4	20.8	6.9	25.2

The data shown in Table XXI are not conclusive. Though the Kherson has yielded as well as any other variety at Carthage, more data are needed before the most desirable varieties for growing in southwestern Missouri can be named definitely.

Results in Arkansas.

The annual and average yields of the Kherson, the Sixty-Day, and six other varieties of oats grown at the Arkansas Agricultural Experiment Station at Fayetteville (30) in the five years from 1909 to 1913, inclusive, are presented in Table XXII.

TABLE XXII.—*Annual and average yields of the Kherson, the Sixty-Day, and six other varieties of oats grown at the Arkansas Agricultural Experiment Station (at Fayetteville) during the 5-year period from 1909 to 1913, inclusive.*

[Data compiled from Arkansas Agricultural Experiment Station Bulletin 118 (30).]

Group and variety.	Yield per acre (bushels).					
	1909	1910	1911	1912	1913	Average.
Early yellow:						
Kherson	21.7	60.0	28.1	17.3	29.5	31.3
Sixty-Day	29.3	47.0	26.2	18.5	30.0	30.2
Early white:						
Daubeney	31.8	60.5	25.7	15.7	35.6	33.9
Early Champion	29.3	56.0	38.4	15.0	29.5	33.6
Early red:						
Burt	19.5	63.5	37.9	22.0	38.9	36.4
Red Rustproof	26.8	72.8	26.0	24.6	22.4	34.5
Winter:						
Winter Turf (Winter Gray)	26.5	48.2	[1]	43.3	41.2	31.8
Winter Turf	32.2	54.0	[1]	43.5	38.2	33.6

[1] Winterkilled.

According to the data shown in Table XXII both the early red and the early white varieties have outyielded the Kherson and Sixty-Day at Fayetteville. The one best variety has been the Burt, which has outyielded the Kherson by slightly more than 5 bushels on the average in the 5-year period from 1909 to 1913, inclusive. The Winter Turf from fall seeding also has exceeded the Kherson and Sixty-Day, even though one crop was entirely lost by winterkilling.

Results in Kansas.

The annual and average yields of the Sixty-Day, the Seventy-five Day, the Kherson, and seven other varieties of oats grown at McPherson, Kans. (12), in four or more years in the 6-year period from 1904 to 1909, inclusive, are shown in Table XXIII.

TABLE XXIII.—*Annual and average yields of the Sixty-Day, the Seventy-five Day, the Kherson, and seven other varieties of oats grown at McPherson, Kans., during four or more years in the 6-year period from 1904 to 1909, inclusive.*[1]

[Data obtained in cooperation with the Kansas Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).							
		1904	1905	1906	1907	1908	1909	Average.	
								1906 to 1909	1904 to 1909
Early yellow:									
Sixty-Day	165	44.9	33.8	43.5	4.7	49.1	53.0	37.6	38.2
Seventy-five Day [2]	337	....	....	[3] 51.2	4.9	39.5	50.8	36.5	....
Kherson	459	....	....	(4)	6.7	41.2	49.9	....	....
Early white:									
Perm	170	....	....	50.2	6.3	37.7	43.1	34.3	....
Early red:									
Red Algerian	286	29.4	[4] 30.7	42.0	5.3	37.1	44.5	32.2	31.5
Burt	293	40.7	27.5	42.2	3.4	34.1	38.3	29.5	31.0
Georgia Rustproof	261	....	....	50.5	8.1	31.6	48.1	34.6	....
Midseason white:									
Canadian	444	....	28.8	37.3	3.6	16.3	33.1	22.6	....
Danish	441	....	26.9	42.4	2.3	16.3	22.8	21.0	......
Late white (side):									
White Tartar	445	....	36.9	44.2	4.7	23.4	34.9	26.8	....

[1] Data previously published in U. S. Dept. Agr., Bur. Plant Indus. Bul. 240 (12).
[2] Similar to Kherson and Sixty-Day.
[3] Yield corrected, or average of two or more plats.
[4] Yield not comparable.

The data in Table XXIII show that the early yellow varieties considerably outyielded all others at McPherson. Their nearest competitor was the Georgia Rustproof, a strain of Red Rustproof. The Perm, a slightly later oat from a more northerly district in Russia, averaged about 3 bushels less than the Sixty-Day. The Seventy-five Day, which, as previously noted, probably is identical with the Sixty-Day, averaged 1 bushel less in a 4-year test. The Sixty-Day exceeded the midseason and late oats by about 50 per cent.

Results in Northeastern Texas.

Varietal experiments with Sixty-Day and several other varieties of oats were conducted by the Texas Agricultural Experiment Station at the Denton substation, near Denton, Tex. (13, p. 9–10), during 1912, 1913, and 1914. The results of these experiments are summarized in Table XXIV.

The data in Table XXIV show that the Sixty-Day in the three years, 1912, 1913, and 1914, was outclassed only by the Red Rustproof, the standard oat variety for that section. The average yields were 38.4 and 41.4 bushels, respectively. The Burt also has been a close competitor of the Sixty-Day. It is believed that the early varieties, such as Sixty-Day and Burt, are particularly valuable for late seeding and dry seasons in the Denton district. Fall-sown Red Rustproof yielded about the same as it did from spring seeding. Typical panicles and spikelets of the Red Rustproof and Burt varieties are shown in figure 8.

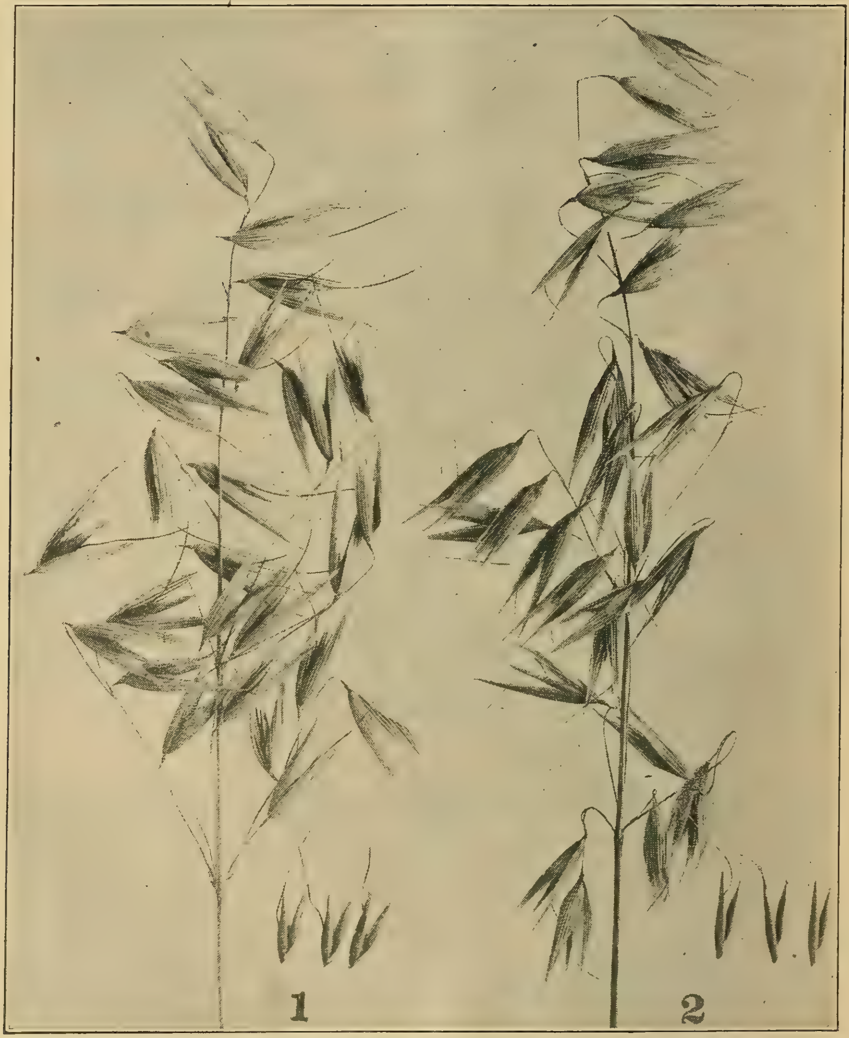

FIG. 8.—Panicles and spikelets of two early red varieties of oats; 1, Red Rustproof; 2, Burt.

TABLE XXIV.—*Annual and average yields of Sixty-Day and five other varieties of oats grown at Texas substation No. 6 (at Denton) in the years 1912, 1913, and 1914.*

[Data compiled from Texas Agricultural Experiment Station Bulletin No. 199 (13, p. 9–10).]

Group and variety.	Texas No.	Yield per acre (bushels).			
		1912	1913	1914	Average.
Early yellow:					
Sixty-Day	430	70.0	33.4	11.8	38.4
Early red:					
Red Rustproof	636	51.1	49.8	23.3	41.4
Burt	433	42.7	45.3	20.1	36.0
Ninety-Day	434	38.0	49.1	19.4	35.5
Red Siberian	432	38.8	34.4	24.7	32.6
Red Algerian	431	32.5	34.4	25.7	30.9

Conclusions.

The average yield of the leading variety in each group at the stations included in the lower Mississippi Valley is shown graphically in figure 9.

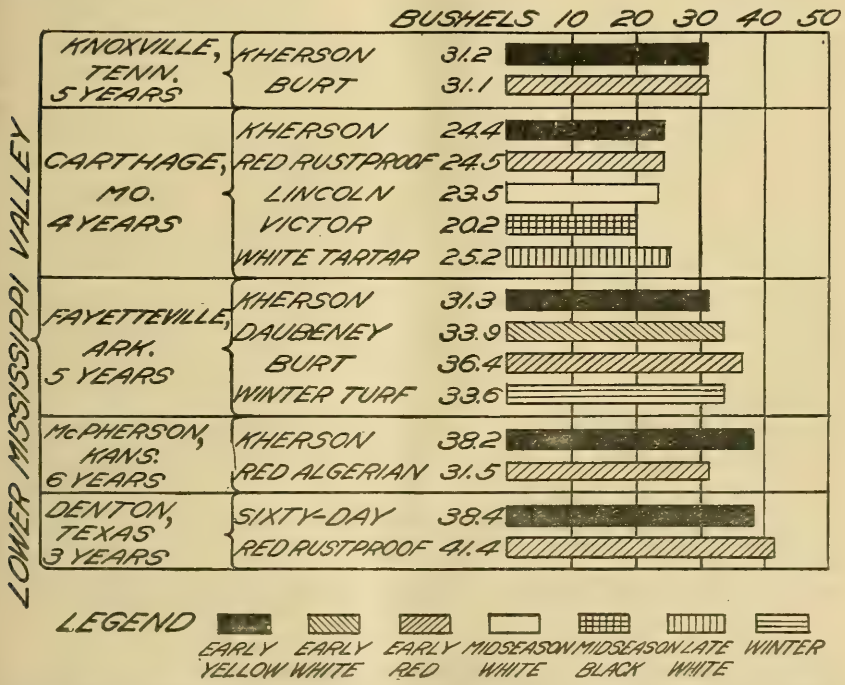

FIG. 9.—Diagram showing the average yields, in bushels per acre, of the highest yielding variety of each of several groups of oats at five agricultural experiment stations in the lower Mississippi Valley during the periods of years indicated.

In general, oat growing, particularly from spring seeding, is not important in the lower Mississippi Valley. The best oat to sow in this section, whether in the fall or in the spring, is the Red Rustproof. The next best variety for spring seeding probably is the Burt, and next to this ranks the Sixty-Day, or Kherson. The Sixty-Day type is not extensively grown in this section, and comparatively few experiments including varieties of this type have been reported.

VARIETAL EXPERIMENTS IN THE WESTERN HALF OF THE UNITED STATES.

In recent years the Kherson and Sixty-Day oats have been included in numerous varietal experiments conducted in the western United States. Because of the rapid agricultural development which is now taking place in this region, there is a great demand for information on the different varieties of the more important grain crops. In consequence, rather extensive varietal experiments with oats have been conducted at numerous stations and the results reported from time to time. Results from 25 experiment stations and farms located in 12 States are presented in this bulletin.

This portion of the United States, including those States from which no experiments with oats have been reported, may be divided as follows: The northern Great Plains area, the southern Great Plains area, and the western Great Basin and coast areas. The few results available from experiments conducted under irrigation also are reported. The general physical data will be discussed separately for each of these three subdivisions.

The experiments at Hays, Kans.; Newell, Highmore, Cottonwood, and Eureka, S. Dak.; Williston and Dickinson, N. Dak.; Moccasin, Mont.; Nephi, Utah; Aberdeen, Idaho; and Burns and Moro, Oreg., have been conducted cooperatively by the United States Department of Agriculture and the State agricultural experiment stations of those States, respectively. At other stations the agencies cooperating with the United States Department of Agriculture have been as follows: Amarillo, Tex., Amarillo Chamber of Commerce; Akron, Colo., and Mandan, N. Dak., Office of Dry-Land Agriculture Investigations; Archer, Wyo., Wyoming Board of Farm Commissioners; and Chico, Calif., Office of Foreign Seed and Plant Introduction. The experiments at North Platte, Nebr.; Edgeley and Langdon, N. Dak.; Reno, Nev.; Bozeman, Mont.; Gooding, Idaho; Pullman and Puyallup, Wash., have been conducted independently by the respective State agricultural experiment stations.

RESULTS IN THE NORTHERN GREAT PLAINS AREA.

The Great Plains area comprises the great extent of gently sloping plain lying between the 98th meridian and the foothills of the Rocky Mountains. The northern Great Plains area includes the semiarid portions of Nebraska and the Dakotas west of the 98th meridian and also northeastern Colorado, eastern Wyoming, and eastern Montana.

Varietal experiments with the Kherson and Sixty-Day oats and a large number of other varieties have been conducted under dry-land conditions at 13 experiment stations in this section during periods varying from 2 to 12 years. The stations are as follows: Moccasin, Mont.; Williston, Dickinson, Mandan, Edgeley, and Langdon, N. Dak.;

Newell, Cottonwood, Eureka, and Highmore, S. Dak.; North Platte, Nebr.; Archer, Wyo.; and Akron, Colo.

The climate of this section is generally semiarid. It is characterized by low precipitation and high summer temperatures. Table XXV shows the altitude, the normal annual and seasonal precipitation, the mean temperatures for June, July, and August, and the general soil type at each of the 13 stations included in the section under consideration.

TABLE XXV.—*Altitude, average annual and seasonal precipitation, mean seasonal temperatures, and general soil types at 13 experiment stations in the northern Great Plains area.*

[The circled figures in columns 6, 7, and 8 indicate the number of years during which the data were recorded when such period was less than the number of years indicated in column 3.]

Station.	Altitude.	Climatological data.						General soil type.
		Length of record.	Average precipitation.		Mean temperature (°F.).			
			Annual.	Seasonal.[1]	June.	July.	August.	
1	2	3	4	5	6	7	8	9
	Feet.	*Years.*	*Inches.*	*Inches.*				
Moccasin, Mont	4,228	19	16.82	10.94	⑧58.0	⑧63.0	⑧63.0	Dark clay loam.
Williston, N. Dak	1,875	33	14.90	10.43	㉚63.0	㉚68.6	㉚66.8	Fine sandy loam.
Dickinson, N. Dak	2,543	25	15.85	11.19	⑰61.0	⑰68.1	⑰67.2	Clay loam to fine sandy loam.
Mandan, N. Dak	1,750	[2]34	17.50	11.71	63.4	69.3	67.6	Sandy loam.
Langdon, N. Dak	1,615	[3]11	16.83	11.09	....	....	....	Black clay loam.
Edgeley, N. Dak	1,468	[4]17	20.25	13.82	....	....	....	Light sandy loam.
Newell, S. Dak	2,950	9	13.98	8.68	65.0	72.0	69.0	Sticky clay (Pierre).
Cottonwood, S. Dak	2,414	7	15.54	9.04	....	....	....	Do.
Eureka, S. Dak	1,884	7	16.43	8.71	....	....	....	Glaciated sandy loam.
Highmore, S. Dak	1,890	22	16.75	10.66	67.7	72.9	71.4	Glaciated clay loam.
North Platte, Nebr	2,826	35	18.74	11.14	㉞68.0	㉞72.2	㉞72.1	Loess.
Archer, Wyo	6,027	[5]39	13.80	7.92	61.0	67.0	65.9	Medium sandy loam with some gravel.
Akron, Colo	4,560	13	19.13	11.90	⑧65.0	⑧71.0	⑧69.0	Sandy loam.

[1] For months of March to July, inclusive, at Akron, Colo., and Newell, S. Dak.; April to July, inclusive, at Archer, Wyo., and North Platte, Nebr., and April to August, inclusive, at Mandan, Edgeley, Dickinson, Williston, and Langdon, N. Dak., Cottonwood, Eureka, and Highmore, S. Dak., and Moccasin, Mont.

[2] Data recorded at Bismarck, N. Dak., about 4 miles east of Mandan; altitude at Bismarck, 1,674 feet.

[3] Data recorded at Woodbridge, about 24 miles northwest of Langdon.

[4] Data recorded at Berlin, about 12 miles east of Edgeley; altitude at Berlin, 1,470 feet.

[5] Data recorded at Cheyenne, Wyo., 8 miles west of Archer; altitude at Cheyenne, 6,088 feet.

As shown in Table XXV there is much variation in the altitude at the different stations. Edgeley, N. Dak., is the lowest, with an elevation of 1,468 feet, and Archer, Wyo., the highest, with an elevation of 6,027 feet above sea level.

The average annual precipitation does not exceed 21 inches at any of these stations. Archer, Wyo., has the lowest precipitation, 13.80 inches. At all stations more than half the precipitation occurs during the late spring and summer months, or during the growing season, when it is most needed by the oat plant.

Results in Montana.[a]

The Kherson and Sixty-Day varieties have been included in the cooperative varietal experiments on the Judith Basin substation at Moccasin, Mont., since work was begun there in 1908. A selection of the Sixty-Day was added in 1910. The following year two more selections of the same variety were included, and in 1916 two selections from Kherson, Albion (Iowa No. 103) and Richland (Iowa No. 105), were added. The annual and average yields of three strains of the Kherson, four strains of the Sixty-Day, and four other varieties of oats grown at Moccasin during two or more years of the 10-year period from 1908 to 1917, inclusive, are shown in Table XXVI.

TABLE XXVI.—*Annual and average yields of seven strains of Kherson and Sixty-Day and of four other varieties of oats grown at the Judith Basin substation, Moccasin, Mont., during two or more years in the 10-year period from 1908 to 1917, inclusive.*[1]

[Data obtained in cooperation with the Montana Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).											
		1908	1909	1910	1911	1913	1914	1915	1916	1917	Average.		
											1908 to 1911 and 1913 to 1917	1913 to 1917	1908 to 1911
Early yellow:													
Kherson	459	20.5	80.6	32.0	67.5	68.4	59.0	90.0	58.0	25.0	55.7	60.1	50.2
Sixty-Day	165	20.5	84.4	33.0	71.2	75.3	59.0	93.7	59.0	28.4	58.3	63.1	52.3
Sixty-Day selection	625	....	....	29.5	58.7	73.4	56.2	88.4	....	....	....	....	....
Do	626	....	....	....	53.7	80.0	56.0	95.6	59.7	24.4	....	63.1	....
Do	789	....	....	....	68.1	78.4	57.2	94.0	63.6	....	....	....	....
Albion (Iowa No. 103, white)	729	....	....	....	....	....	....	....	40.3	29.0	....	....	....
Richland (Iowa No. 105)	787	....	....	....	....	....	....	....	52.5	27.0	....	....	....
Early white:													
Early Champion	....	10.0	67.2	5.7	(2)	....	....	....	....	....	....	....	20.7
Midseason white:													
Danish	441	20.0	76.8	23.6	(2)	56.2	47.3	100.0	59.4	25.3	45.4	57.6	30.1
Swedish Select	134	15.0	77.0	22.3	(2)	53.1	50.0	108.0	65.7	22.5	46.0	59.9	28.6
Late white (side):													
White Tartar	300	13.3	67.3	18.0	(2)	....	....	....	....	....	....	....	24.7

[1] Crop destroyed by hail in 1912.

[2] Made second growth during rainy weather in August; not ripe when first frost came.

Reference to Table XXVI shows rather conclusively that the early varieties, Kherson and Sixty-Day, outyielded all other oats at Moccasin. The difference in yield in favor of these varieties over the midseason varieties is more than 10 bushels on the 9-year average. The Early Champion, an early white open-panicled variety, and the White Tartar, a late side oat, grown from 1908 to 1911, yielded much less each year than the Kherson and Sixty-Day. The two pure-line selections of Sixty-Day (C. I. Nos. 626 and 789) slightly exceeded the unselected Kherson and Sixty-Day in average yield.

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[a] Data compiled from U. S. Department of Agriculture Bulletin 398 (14), and from unpublished annual reports of Mr. N. C. Donaldson, formerly scientific assistant in charge of cereal experiments at the Judith Basin substation, to the Office of Cereal Investigations.

Neither the Albion nor Richland, the two selections from Kherson, has yielded so well in the two years in which they have been tested as the original Kherson and Sixty-Day.

Results in North Dakota.

RESULTS AT WILLISTON.[1]

The Sixty-Day oat has been included in the varietal experiments at Williston since 1908, while the Kherson has been grown only since 1914. Two selections from Kherson, Albion (Iowa No. 103) and Richland (Iowa No. 105), were added to the tests in 1916. The annual and average yields of these and six other varieties which have been grown three or more years in the 10-year period from 1908 to 1917, inclusive, are presented in Table XXVII.

TABLE XXVII.—*Annual and average yields of the Sixty-Day, Kherson, and eight other varieties of oats grown at the Williston (N. Dak.) substation during two or more years in the 10-year period from 1908 to 1917, inclusive.*

[Data obtained in cooperation with the North Dakota Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).												
		1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Average.		
												1908 to 1917	1914 to 1917	1916 and 1917
Early yellow:														
Sixty-Day	165	28.8	76.3	4.2	11.2	50.3	45.0	82.2	85.1	78.8	44.3	50.6	72.6	61.6
Kherson	459	....	.....	....	....	.....	....	78.9	80.4	90.1	49.0	....	74.6	69.6
Albion (Iowa No. 103, white)	729	....	.....	....	....	.....	....	.....	.....	89.4	50.6	....	....	70.0
Richland (Iowa No. 105)	787	....	.....	....	....	.....	....	.....	.....	83.8	43.4	....	....	63.6
Midseason white:														
Abundance (N. Dak. No. 966)	731	31.3	91.1	12.5	7.7	104.7	93.4	123.9	99.4	103.2	47.5	71.5	93.5	75.4
Lincoln (N. Dak. No. 48)	738	32.1	96.2	15.6	7.0	101.3	84.5	124.3	99.1	101.9	45.6	70.8	92.7	73.8
Silvermine (N. Dak. No. 723)	714	37.4	103.3	14.8	7.3	95.7	67.5	120.7	100.0	101.9	46.6	69.5	92.3	74.3
Siberian (N. Dak. No. 864)	741	29.0	104.1	10.9	5.1	106.9	79.4	116.4	94.7	95.1	44.4	68.6	87.7	69.8
Swedish Select	134	28.4	86.0	7.8	9.9	84.4	68.8	97.3	101.7	97.8	41.8	62.4	84.7	69.8
Late white (side):														
White Russian (N. Dak. No. 51)	732	23.0	70.8	13.0	2.9	120.6	80.3	102.0	86.4	78.8	36.9	61.5	76.0	57.9

The results given in Table XXVII show that the Sixty-Day and Kherson do not yield nearly as well at Williston as the later or midseason varieties. The best of the midseason white varieties have decidedly outyielded the Kherson and Sixty-Day and therefore are to be recommended. In the 10-year period from 1908 to 1917, inclusive, the four highest yielding varieties of this group, viz, Abundance, Lincoln, Silvermine, and Siberian, have averaged 71.5, 70.8, 69.5, and 68.6 bushels, respectively, as compared with 50.6 bushels for the Sixty-Day. A strain of the White Russian, a late side oat, has also outyielded the Sixty-Day by about 11 bushels.

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[1] Data from U. S. Department of Agriculture Bulletin 270 (4), 1915, and from annual reports of Mr. F. Ray Babcock, formerly scientific assistant in charge of cereal experiments at the Williston substation, to the Office of Cereal Investigations.

RESULTS AT DICKINSON.[a]

The Kherson and Sixty-Day oats have been included in the cooperative experiments at Dickinson since they were begun in 1907. Two selections from Kherson, Albion (Iowa No. 103) and Richland (Iowa No. 105), were added to the experiments in 1916. The annual and average yields of these and of ten other varieties of oats grown at Dickinson for two or more years in the 11-year period from 1907 to 1917, inclusive, are presented in Table XXVIII.

TABLE XXVIII.—*Annual and average yields of the Kherson, Sixty-Day, and ten other varieties of oats grown at the Dickinson (N. Dak.) substation during two or more years in the 11-year period from 1907 to 1917, inclusive.*

[Data obtained in cooperation with the North Dakota Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).													
		1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Average. 1907 to 1917	Average. 1911 to 1917	Average. 1916 and 1917
Early yellow:															
Kherson	459	75.3	48.1	81.3	46.2	16.7	50.9	45.0	26.5	92.5	66.8	12.5	51.1	44.4	39.7
Sixty-Day	165	58.2	37.2	....	45.0	22.8	42.2	42.2	23.0	104.0	74.3	12.0	....	45.8	43.2
Albion (Iowa No. 103, white)	729	....	....	....	....	....	....	....	....	....	65.8	14.1	....	....	40.0
Richland (Iowa No. 105)	787	....	....	....	....	....	....	....	....	....	73.6	15.3	....	....	44.5
Midseason yellow:															
Golden Rain	493	35.2	52.8	82.2	35.6	14.4	62.8	70.9	20.0	129.3	66.8	18.0	53.5	54.6	42.4
Golden Beauty	169	....	....	....	....	....	....	76.3	25.2	121.2	71.0	20.2	....	....	45.6
Midseason white:															
Banner	160	46.8	41.6	89.4	(1)	6.2	65.0	48.1	17.7	117.8	54.3	17.6	45.9	46.7	36.0
Swedish Select	134	46.9	....	81.3	38.1	5.6	[2]52.3	61.9	16.8	101.5	75.0	21.6	....	47.8	48.3
Victory	560	....	42.5	88.3	(1)	8.9	59.4	70.6	18.6	123.9	79.2	22.2	....	54.7	50.7
Big Four	658	....	35.3	84.7	(1)	7.9	60.2	65.6	29.3	109.8	75.7	19.3	....	52.5	47.5
Silvermine	659	....	....	64.1	(1)	8.1	55.8	66.9	17.3	117.3	78.3	21.8	....	52.2	50.1
Early Mountain No. 2	656	....	....	....	(1)	[3]11.3	58.6	[4]67.3	24.8	105.3	74.7	18.7	....	51.5	46.7
Siberian	741	....	....	....	....	....	....	....	16.0	121.8	79.2	19.0	....	....	49.1
Late white (side):															
White Russian	551	62.8	28.1	64.3	(1)	14.3	(1)	53.4	24.5	99.8	74.0	10.5	39.2	39.5	42.3

[1] Destroyed by hail.
[2] Average of four check plats.
[3] Average of five check plats.
[4] Average of six check plats.

Only four varieties have been grown continuously since 1907. Of these, Golden Rain, a midseason yellow variety, has yielded best, with Kherson a close second. The materially lower yields of the other two varieties, Banner and White Russian, are due to the fact that hail destroyed the Banner in one year and the White Russian in two years, after the earlier varieties were harvested. The Sixty-Day has averaged 2 bushels less than the Kherson in the years both have been grown, but since 1910 it has averaged about 1 bushel more. Several varieties have been grown continuously in the 7-year period from 1911 to 1917, inclusive. In this period the Victory has outyielded all others, with Golden Rain ranking a very close second. Both these varieties are pure-line selections developed in

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[a] Data from U. S. Department of Agriculture Bulletin 33 (11), and from annual reports of Mr. Ralph W. Smith, scientific assistant in charge of cereal experiments at the Dickinson (N. Dak.) substation, to the Office of Cereal Investigations.

Sweden. All the midseason varieties have outyielded the Sixty-Day and Kherson, which in turn have outyielded the late side oat, White Russian. From these results it appears that the better midseason varieties are to be preferred to the early ones for this section.

RESULTS AT MANDAN.[1]

The Sixty-Day oat has been included in varietal experiments at the Northern Great Plains Field Station, Mandan, N. Dak., since 1916. The annual and average yields of this and five other varieties grown during the years 1916 and 1917 are shown in Table XXIX.

TABLE XXIX.—*Annual and average yields of the Sixty-Day and five other varieties of oats grown at the Northern Great Plains Field Station, Mandan, N. Dak., during the years 1916 and 1917.*

[Data obtained in cooperation with the Office of Dry-Land Agriculture.]

Group and variety.	C. I. No.	Yield per acre (bushels).		
		1916	1917	Average.
Early yellow:				
Sixty-Day	165	46.4	41.3	43.9
Midseason yellow:				
Golden Rain	493	53.6	44.3	49.0
Midseason white:				
Victory	560	51.4	45.2	48.3
Early Mountain	656	54.3	32.0	43.2
Swedish Select	134	41.6	40.7	41.2
Late white (side):				
White Russian	744	48.0	37.6	42.8

The data shown in Table XXIX indicate that the best midseason varieties probably will outyield the Sixty-Day in central North Dakota, but data covering only two years are not sufficient to justify the drawing of definite conclusions. The results, however, are in accord with those obtained at Dickinson.

RESULTS AT LANGDON.

The annual and average yields of the Sixty-Day and six other varieties of oats grown at the Langdon substation (39) during the 5-year period from 1909 to 1913, inclusive, are presented in Table XXX.

TABLE XXX.—*Annual and average yields of the Sixty-Day and six other varieties of oats grown at the Langdon (N. Dak.) substation during the 5-year period from 1909 to 1913, inclusive.*

[Data compiled from annual reports of the Langdon subexperiment station (39).]

Group and variety.	Yield per acre (bushels).					
	1909	1910	1911	1912	1913	Average.
Early yellow:						
Sixty-Day	[2]66.8	8.0	40.0	54.7	36.3	41.2
Midseason white:						
Siberian	56.7	15.5	71.3	80.3	48.3	54.4
Big Four	72.0	14.8	64.4	66.7	45.3	52.6
Swedish Select	74.4	14.0	60.2	66.1	45.0	51.9
Late white (side):						
White Russian	60.0	20.8	76.5	73.4	57.0	57.5
Select Tartarian	54.0	20.3	75.8	80.5	53.8	56.9
New Zealand	50.0	21.3	76.5	78.1	56.0	56.4

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[1] Data from unpublished annual reports of Mr. J. C. Brinsmade, jr., scientific assistant in charge of cereal experiments at the Northern Great Plains Field Station, to the Office of Cereal Investigations.

[2] Yield of the early yellow strain known as Seventy-five Day.

The data in Table XXX show that both the midseason and late white oats have decidedly outyielded the Sixty-Day at the Langdon substation.

The yields of the side-oat varieties, New Zealand, White Russian, and Select Tartarian, have averaged several bushels more than those of the midseason open-panicled varieties. This condition occurs so rarely that it seems worthy of special mention. Early oats are not recommended for this section of North Dakota. A panicle and spikelets of the White Russian oat are shown in figure 10.

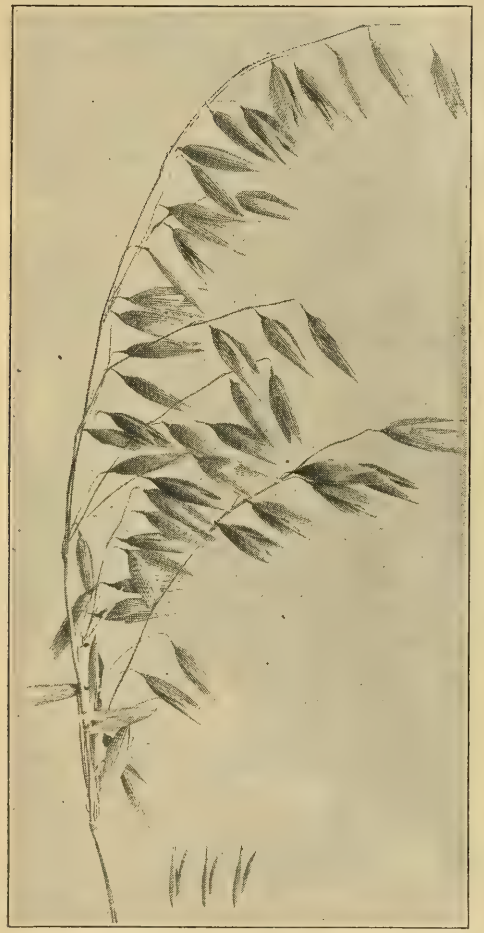

FIG. 10.—Panicle and spikelets of a late white (side) variety of oats, White Russian.

RESULTS AT EDGELEY.

The annual and average yields of the Sixty-Day, the Kherson, and seven other varieties of oats grown at the Edgeley, N. Dak., substation (45, p. 28) during three or more years in the 10-year period from 1903 to 1912, inclusive, are presented in Table XXXI.

According to the data given in Table XXXI there is little choice between the early yellow and the midseason white varieties for growing in the vicinity of Edgeley. Only the Siberian, Sixty-Day, and Swedish Select have been grown during the entire period. They rank in average yield in the order named. In the six years from 1905 to 1910, inclusive, the Abundance, Big Four, Siberian, and Sixty-Day produced almost identical average yields. The results appear to be slightly in favor of the midseason varieties. It is probable that the rather thin soil of this section accounts for the better performance of early oats at Edgeley than elsewhere in North Dakota.

TABLE XXXI.—*Annual and average yields of the Kherson, the Sixty-Day, and seven other varieties of oats grown at the Edgeley (N. Dak.) substation during three or more years in the 10-year period from 1903 to 1912, inclusive.*

[Data compiled from the Tenth Annual Report of the Edgeley (N. Dak.) substation (45, p. 28).]

Group and variety.	Yield per acre (bushels).										
	1903	1905	1906	1907	1908	1909	1910	1912	Average.		
									1903, 1905 to 1910, and 1912	1908 to 1910	1905 to 1910
Early yellow:											
Sixty-Day	37.0	90.9	51.4	13.8	26.9	62.2	19.3	37.4	42.4	36.1	44.1
Kherson	......	......	......	......	27.4	67.8	24.3	......	....	39.8	......
Midseason white:											
Siberian	46.3	91.2	64.8	24.3	12.7	65.9	6.3	52.5	45.5	28.3	44.2
Swedish Select	41.4	71.8	52.7	15.4	13.7	45.6	7.4	43.7	36.5	22.2	34.4
Silvermine	......	90.7	56.7	19.9	12.7	60.3	7.4	......	....	26.8	41.3
Big Four	......	85.1	70.4	23.5	13.7	63.1	10.5	55.8	....	29.1	44.4
Abundance	......	90.2	73.3	24.3	15.8	64.7	5.3	......	....	28.6	45.6
Late white (side):											
White Russian	......	78.3	79.8	24.4	4.3	35.7	2.1	......	....	14.0	37.4
Select Tartarian	31.9	74.9	57.5	22.7	3.2	37.6	3.1	......	....	14.6	33.2

Results in South Dakota.[1]

RESULTS AT NEWELL.

The original strains of Kherson and Sixty-Day oats have been included in the varietal experiments at Newell since 1908. In 1910 two selections of the Sixty-Day were added and in 1912 two more of the same variety. These have been continued to date, except that one of the selections was not grown in 1916 and 1917. In addition, the strain known as Seventy-five Day was included for several years. Aside from the early yellow strains, seven other varieties have been grown in four or more years in the 9-year period from 1908 to 1916, inclusive. The annual and average yields of the leading selections and varieties grown at Newell are presented in Table XXXII.

The data given in Table XXXII indicate that the early yellow varieties, Kherson and Sixty-Day, are the most dependable for western South Dakota. The average yield of the Kherson in the 10-year period from 1908 to 1917, inclusive, is 31.6 bushels, compared with 26 and 22.7 bushels from Swedish Select and White Russian, respectively. In the 6-year period from 1912 to 1917, inclusive, a white-kerneled selection of Sixty-Day, C. I. No. 626, has outyielded the Kherson, Burt, Swedish Select, and White Russian varieties by 3, 2.9, 9.1, and 11.5 bushels, respectively.

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[1] Data obtained cooperatively by the South Dakota station and the Bureau of Plant Industry. Data previous to 1914 were published in U. S. Department of Agriculture Bulletin 39 (10); in South Dakota Agricultural Experiment Station Bulletin 149 (17), and in U. S. Department of Agriculture Bulletin 297 (32).

TABLE XXXII.—*Annual and average yields of eight early yellow and four other varieties of oats grown at the Belle Fourche Experiment Farm, Newell, S. Dak., during two or more years in the 10-year period from 1908 to 1917, inclusive.*

[Data obtained in cooperation with the South Dakota Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).												
		1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Average.		
												1908 to 1917	1912 to 1917	1912 to 1915
Early yellow:														
Kherson	459	[1]47.5	[1]25.7	[1]15.0	0	6.2	21.9	13.8	110.8	40.8	33.8	31.6	37.9	38.2
Sixty-Day	165	[1]46.6	25.0	15.6	0	6.6	22.7	....	113.7	37.4	34.1	....	....	....
Sixty-Day selection	625	.....	.....	14.4	0	7.9	21.6	13.4	107.2	....	....	....	....	37.5
Do	626	.....	.....	16.6	0	9.9	24.6	14.2	117.1	43.4	35.9	....	40.9	41.5
Do	165-566	.....	.....	.....	....	7.1	23.3	12.2	106.7	41.8	33.8	....	37.5	37.3
Albion (Iowa No. 103, white)	729	.....	.....	.....	....	....	....	....	.....	35.6	30.6	....	....	....
Richland (Iowa No. 105)	787	.....	.....	.....	....	....	....	....	.....	33.5	30.6	....	....	....
Seventy-five Day	337	.....	.....	.....	....	7.5	21.0	12.8	102.5	....	....	....	....	36.0
Early red:														
Burt	293	.....	.....	.....	....	6.0	22.4	16.0	108.0	38.0	37.4	....	38.0	38.1
Midseason white:														
Swedish Select	134	38.1	28.4	2.3	0	9.2	15.2	0	113.7	33.0	19.7	26.0	31.8	34.5
Canadian	444	38.8	21.3	4.4	0	10.4	18.5	0	92.9	....	....	....	....	30.5
Late white (side):														
White Russian	551	30.9	20.0	0	0	22.7	14.3	0	106.1	26.8	6.4	22.7	29.4	35.8

[1] Average of two plats.

RESULTS AT COTTONWOOD.

The only varieties included in the experiments at the Cottonwood substation are the Sixty-Day and the Swedish Select. In Table XXXIII the annual and average yields of these varieties obtained at Cottonwood during the 9-year period from 1909 to 1917, inclusive, are presented.

TABLE XXXIII.—*Annual and average yields of the Sixty-Day and Swedish Select oat varieties grown at the Cottonwood and Eureka (S. Dak.) substations during the 9-year period from 1909 to 1917, inclusive.*

[Data obtained in cooperation with the South Dakota Agricultural Experiment Station.]

Station, group, and variety.	South Dakota No.	C. I. No.	Yield per acre (bushels).									
			1909	1910	1911	1912	1913	1914	1915	1916	1917	Average.
COTTONWOOD SUBSTATION.												
Early yellow: Sixty-Day	165	165	12.5	4.4	0	25.9	4.7	[1]14.8	[2]0	29.1	24.7	12.9
Midseason white: Swedish Select	112	134	7.2	6.3	0	16.6	.6	[1]9.4	[2]0	15.9	10.3	7.4
EUREKA SUBSTATION.												
Early yellow: Sixty-Day	165	165	37.2	20.2	0	6.1	15.8	37.5	110.6	60.1	46.2	37.1
Midseason white: Swedish Select	112	134	43.7	25.0	0	4.7	3.3	28.5	95.8	53.7	35.8	32.3

[1] Yield from method-of-seeding experiment at Cottonwood.

[2] Destroyed by hail.

The data given in Table XXXIII indicate that the Sixty-Day is superior to the Swedish Select for growing in the vicinity of Cottonwood, though neither variety has produced profitable yields.

RESULTS AT EUREKA.

The only two varieties which have been grown at the Eureka substation, as at Cottonwood, are the Sixty-Day and the Swedish Select. These two varieties have been grown at that point continuously since 1909. Their annual and average yields in the 9-year period from 1909 to 1917, inclusive, are shown in Table XXXIII.

The results shown in Table XXXIII indicate that the Sixty-Day will outyield the Swedish Select variety under conditions similar to those at Eureka. The difference between the 9-year average yields of the two varieties is 4.8 bushels.

RESULTS AT HIGHMORE.

The Kherson and Sixty-Day oats have been included in the cooperative varietal experiments at Highmore since 1906. The annual and average yields of these and five other varieties of oats grown at Highmore in five or more years in the 12-year period from 1906 to 1917, inclusive, are presented in Table XXXIV.

TABLE XXXIV.—*Annual and average yields of the Kherson, the Sixty-Day, and five other oat varieties grown at the Highmore (S. Dak.) substation during five or more years in the 12-year period from 1906 to 1917, inclusive.*

[Experiments conducted in cooperation with the South Dakota Agricultural Experiment Station.]

Group and variety.	S. Dak. No.	C. I. No.	Yield per acre (bushels).													
			1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Average.	
															1906 to 1917	1906 to 1913
Early yellow:																
Sixty-Day	165	165	43.3	31.6	47.5	28.8	9.4	0	1.2	9.1	50.8	128.1	68.7	25.7	37.0	21.4
Kherson	115	539	69.7	28.8	39.0	21.9	10.0	0	.7	7.8	....	.....	....	....	.....	22.2
Early black:																
North Finnish Black	174	174	58.8	25.0	26.3	30.6	19.4	0	.3	.6	40.6	.....	....	....	.....	20.1
Early red:																
Red Algerian	286	286	49.1	21.9	32.8	23.4	35.0	0	(1)	....	....	.....	....	....	.....	.....
Midseason white:																
Swedish Select	112	134	65.0	30.8	30.3	36.6	25.0	0	.3	.9	34.4	93.8	40.6	12.1	30.8	23.6
Belyak	336	336	55.6	26.6	21.3	28.8	36.9	0	.7	.3	49.9	68.8	....	....	.....	21.3
Late white (side):																
White Tartar	....	445	44.7	26.3	25.0	4.7	....	0	(1)	....	....	.....	....	....	.....	.....

[1] While very small yields were obtained in 1912, they were not sufficient to pay for harvesting and are, therefore, not considered.

Reference to Table XXXIV shows that the Sixty-Day has outyielded all other varieties at Highmore. The Kherson slightly exceeded it in average yield during the years it was grown, due to a wide difference in the yields of the 1906 crop. Except in this year the Sixty-Day usually has yielded more, and the Kherson has been discarded. The 12-year average of the Sixty-Day is 6.2 bushels higher than that of the Swedish Select, the highest yielding midseason white variety.

Results in Nebraska.

Table XXXV presents the annual and average yields of the Kherson, the Sixty-Day, and four other varieties of oats grown at the North Platte (Nebr.) substation (36, p. 17–18) during four or more years in the 9-year period from 1904 to 1912, inclusive.

TABLE XXXV.—*Annual and average yields of the Kherson, the Sixty-Day, and four other varieties of oats grown at the North Platte (Nebr.) substation during four or more years in the 9-year period from 1904 to 1912, inclusive.*[1]

[Data compiled from Nebraska Agricultural Experiment Station Bulletin 135 (36, p. 17–18).]

Group and variety.	Yield per acre (bushels).								
	1904	1905	1906	1908	1909	1910	1912	Average.	
								1905, 1906, and 1908 to 1910, inclusive.	1908 to 1910 and 1912.
Early yellow:									
Kherson	48.0	20.0	47.0	50.9	40.0	19.0	6.8	35.4	29.2
Sixty-Day	48.0	20.0	47.8	......	36.0	15.9	8.8	......	......
Early red:									
Red Rustproof (Texas Red)	......	29.0	43.3	40.7	38.2	9.8	......	32.2	......
Red Algerian	......	......	......	27.2	34.2	5.0	7.5	......	18.5
Burt	......	......	......	50.7	38.2	19.0	15.8	......	30.9
Midseason white:									
Swedish Select	......	......	......	34.1	23.4	6.7	2.0	......	16.6

[1] The varieties in 1907 were destroyed by freezing, and in 1911 the crop was a total failure, due to drought.

The data shown in Table XXXV indicate that the Kherson and the Sixty-Day varieties are superior to all others at North Platte, although the Burt has outyielded the Kherson in the four years, 1908, 1909, 1910, and 1912, by 1.7 bushels. Varieties other than the Sixty-Day, Kherson, Burt, and Red Rustproof are of little value in central and western Nebraska.

Results in Wyoming.[1]

The Kherson and Sixty-Day varieties have been included in the varietal experiments at the Cheyenne Experiment Farm, Archer, Wyo., since work was begun there in 1913. Two selections of Kherson from the Iowa station have been grown since 1916. Table XXXVI shows the annual and average yields of the unselected Kherson and Sixty-Day and of five other varieties of oats grown at Archer in the 5-year period from 1913 to 1917, inclusive, together with the yields of the two Kherson selections in 1916 and 1917.

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[1] The results obtained in 1913, 1914, and 1915 were reported in U. S. Department of Agriculture Bulletin 430 (19). Later data are compiled from unpublished reports of Mr. V. H. Florell, scientific assistant, formerly in charge of cereal experiments at the Cheyenne Experiment Farm, to the Office of Cereal Investigations.

TABLE XXXVI.—*Annual and average yields of three strains of the Kherson, one strain of the Sixty-Day, and five other varieties of oats grown at the Cheyenne Experiment Farm, Archer, Wyo., in the 5-year period from 1913 to 1917, inclusive.*

[Experiments conducted in cooperation with the Wyoming State Board of Farm Commissioners.]

Group and variety.	C. I. No.	Yield per acre (bushels).					
		1913	1914	1915	1916	1917	Average.
Early yellow:							
Sixty-Day	165	15.8	25.6	[1] 29.9	9.6	27.4	21.7
Kherson	459	[2] 12.5	[2] 27.5	[1] 29.3	9.9	27.1	21.3
Albion (Iowa No. 103, white)	729	....	....	....	[3] 5.0	25.7	....
Richland (Iowa No. 105)	787	....	....	....	9.0	27.0	....
Midseason yellow:							
Probsteier	495	12.2	22.5	45.0	6.3	32.0	23.6
Midseason white:							
Swedish Select	134	10.0	26.7	52.1	7.7	35.3	26.4
Ligowo	492	10.5	23.6	48.7	8.6	40.3	26.3
Colorado No. 37	619	7.2	24.7	51.5	6.3	38.1	25.6
Late black (side):							
Black Tartarian	768	7.8	18.8	41.5	4.9	31.3	20.9

[1] Damaged about 30 per cent by hail.
[2] Average of six tenth-acre check plats.
[3] Not comparable. A poor stand occurred, due to poor germination.

Table XXXVI shows that the three varieties classed as midseason white have outyielded the Sixty-Day and the Kherson. The best midseason white oat, Swedish Select, has outyielded the Kherson by 4.7 bushels. The Probsteier, a midseason yellow variety, also has outyielded both the Sixty-Day and the Kherson by about 2 bushels.

Although these tests have not been of sufficient duration to be conclusive, the evidence indicates that in this section of the Great Plains the midseason white varieties generally will outyield the Kherson and Sixty-Day and therefore are to be recommended.

Results in Colorado.[1]

Kherson and Sixty-Day oats have been included in the varietal experiments at the Akron (Colo.) Field Station since they were begun in 1908. The annual and average yields of these two varieties, three selections from them, and five other varieties of oats grown in one or more years in the 10-year period from 1908 to 1917, inclusive, are presented in Table XXXVII.

The data shown in Table XXXVII indicate that there is little choice at Akron between the Kherson and Sixty-Day and the midseason white varieties, Colorado No. 37 and Swedish Select. The Kherson has outyielded the Colorado No. 37 by a little more than 2 bushels, but the Sixty-Day has fallen below both the Colorado No. 37 and the Swedish Select by about the same quantity. A comparison of the yields for the years 1912 to 1917 shows that Burt, an early red oat, has slightly outyielded the Kherson. In this period the Kherson has outyielded the best Sixty-Day strain by about 3 bushels and Colorado No. 37, the best of the midseason white varieties at Akron, by 7 bushels.

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[1] The results obtained in 1915 and previous years were reported in U. S. Department of Agriculture Bulletin 402 (25). Later data are compiled from unpublished annual reports of Mr. George A. McMurdo, formerly scientific assistant in charge of cereal experiments at the Akron Field Station (1916) and Mr. F. A. Coffman, now scientific assistant in charge at Akron, to the Office of Cereal Investigations.

TABLE XXXVII.—*Annual and average yields of the Kherson, the Richland, the Albion, two strains of the Sixty-Day, and five other varieties of oats grown at the Akron (Colo.) Field Station durinj one or more years in the 10-year period from 1908 to 1917, inclusive.*

[Experiments conducted in cooperation with the Office of Dry-Land Agriculture Investigations.]

Group and variety.	C. I. No.	Yield per acre (bushels).												
		1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Average.		
												1908 to 1917	1912 to 1917	1916 to 1917
Early yellow:														
Kherson	459	52.8	33.1	37.1	12.4	36.0	36.1	65.0	85.0	16.8	14.7	38.9	42.3	15.8
Sixty-Day	165	42.9	37.2	21.9	3.3	33.4	28.1	65.0	82.6	12.5	14.9	34.2	39.4	13.7
Sixty-Day selection 4P2	788	.....	.....	32.0	4.2	40.0	26.2	61.2	74.2	9.3	.....	.....	.....	.....
Albion (Iowa No. 103, white)	729	.....	.....	.....	.....	.....	.....	.....	.....	8.6	24.0	.....	.....	16.3
Richland (Iowa No. 105)	787	.....	.....	.....	.....	.....	.....	.....	.....	12.5	.....	.....	.....	.....
Early red:														
Burt	293	.....	.....	.....	.....	48.2	36.8	63.1	82.6	11.7	13.9	.....	42.7	12.8
Midseason white:														
Colorado No. 37	619	36.8	55.6	29.9	[1]32.5	30.9	32.5	53.7	79.2	7.4	7.9	36.6	35.3	7.7
Swedish Select	134	62.5	50.6	29.5	15.9	30.9	27.5	48.7	69.4	10.5	9.2	35.5	32.7	9.9
Lincoln	738	.....	.....	.....	.....	.....	41.2	61.2	67.8	9.4	9.4	.....	.....	9.4
Late white (side):														
White Tartar	300	19.7	.....	.....	.....	23.4	23.7	42.1	65.0	0.7	4.1	.....	26.5	2.4

[1] Plat favorably located with regard to soil moisture. Under comparable conditions this variety would have yielded about the same as Swedish Select.

The Tartarian, a late white side oat, has an average yield of only 26.5 bushels for the same period, as compared with Burt, Kherson, Colorado No. 37, and Swedish Select, with 42.7, 42.3, 35.3, and 32.7 bushels, respectively. Early Champion, grown in 1908, 1909, and 1910 only, averaged 7 bushels to the acre less than Kherson in the same years.

Conclusions.

The average yield of the leading variety in each group at the stations included in the northern Great Plains is shown graphically in figure 11.

Except at the higher elevations in the northern Great Plains and in the extreme north, Sixty-Day and Kherson oats usually yield better than other varieties.

At the Judith Basin substation, in central Montana, Sixty-Day and Kherson oats have yielded slightly better than the midseason varieties.

At the Edgeley substation, in southeastern North Dakota, the Sixty-Day oat has yielded about the same as the best midseason varieties, but at other stations in the central and western portions of North Dakota, midseason varieties, such as Victory, Golden Rain, and Silvermine, have yielded considerably better than the early oats.

At several stations in central and western South Dakota, the Sixty-Day and Kherson oats have yielded better than the midseason and late varieties and are generally to be recommended in that State.

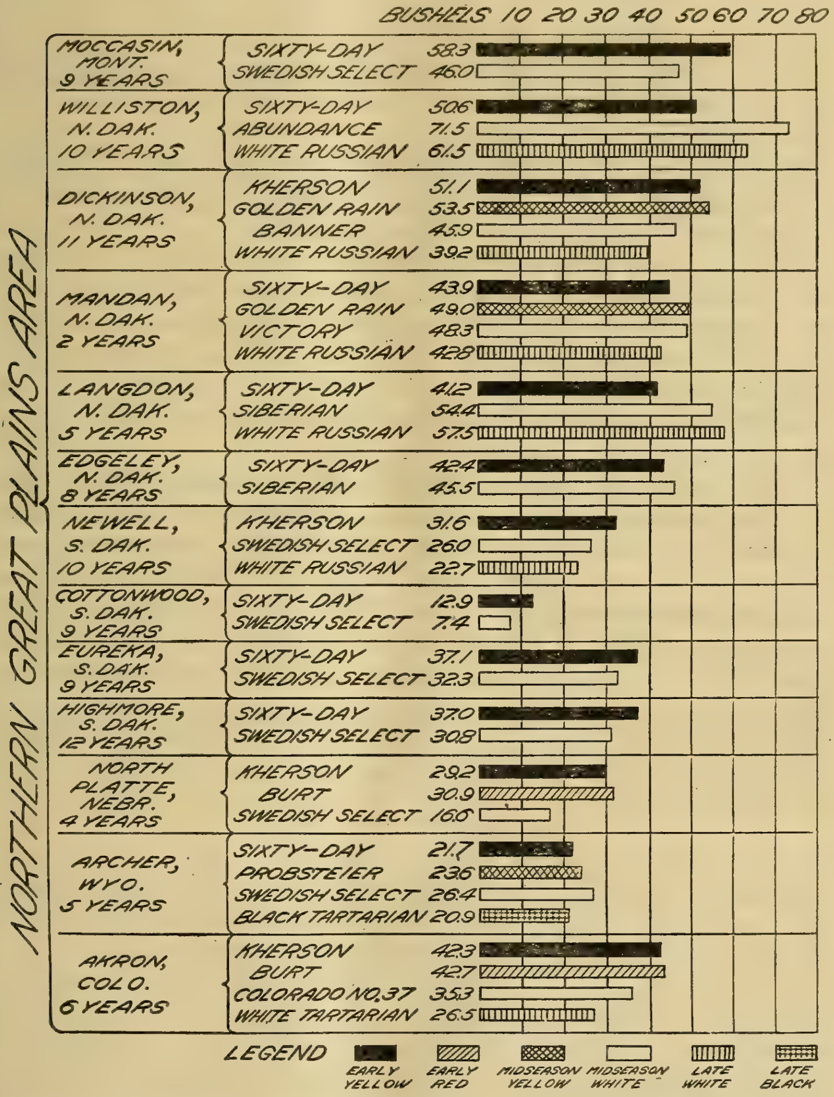

FIG. 11.—Diagram showing the average yields, in bushels per acre, of the highest yielding variety of each of several groups of oats at thirteen agricultural experiment stations in the northern Great Plains area during the periods of years indicated.

At the North Platte substation in western Nebraska, the Burt. Red Rustproof, Kherson, and Sixty-Day oats have yielded equally well, exceeding considerably the later varieties.

At the Akron substation, in northeastern Colorado, there is little choice between the early and midseason varieties. At the Cheyenne Field Station, at an altitude of 6,000 feet, in southeastern Wyoming, the midseason varieties of oats have yielded better than the early ones.

RESULTS IN THE SOUTHERN GREAT PLAINS AREA.

The southern Great Plains include the western or semiarid portions of Texas, Oklahoma, and Kansas, southeastern Colorado, and eastern New Mexico.

The oat crop is not grown extensively in this area. The early red varieties, Red Rustproof and Burt, and the early yellow varieties, Kherson and Sixty-Day, are the most popular.

Varietal experiments with the Kherson, the Sixty-Day, and other oat varieties have been conducted under dry-land conditions at only two experiment stations in this section. The Kherson and the Sixty-Day varieties have been under test at the Amarillo Cereal Field Station, Amarillo, Tex., since 1906. Comparable data are available from the Hays Branch Experiment Station, Hays, Kans., only since 1913.

The climate of this section, like that of the northern Great Plains area, is generally classed as semiarid. As crop production is largely governed by climatic conditions, the altitude, the quantity and distribution of the annual precipitation, the normal annual and seasonal precipitation, and the mean temperatures for June, July, and August at Hays, Kans., and Amarillo, Tex., are shown in Table XXXVIII. The general soil type at each station also is shown.

TABLE XXXVIII.—*Altitude, average annual and seasonal precipitation, mean seasonal temperatures, and general soil types at the Hays (Kans.) Branch Experiment Station and the Amarillo (Tex.) Cereal Field Station.*

Station.	Altitude.	Climatological data.						General soil type.
		Length of record.	Average precipitation.		Normal temperature (°F).			
			Annual.	Seasonal.[1]	June.	July.	August.	
	Ft.	*Yrs.*	*Ins.*	*Ins.*				
Hays, Kans.	2,000	48	23.16	17.67	[2] 71.6	[2] 76.8	[2] 76.9	Silty clay loam.
Amarillo, Tex.	3,676	26	20.89	15.67	[3] 72.0	[3] 75.3	[3] 75.3	Chocolate clay loam.

[1] April to September, inclusive. [2] Twelve-year average. [3] Eighteen-year average.

Table XXXVIII shows that the greater portion of the precipitation occurs during the growing season, when the need for it is greatest. The high mean temperatures and high wind movement cause rapid loss of water by evaporation. As oats require more water than any other small-grain crop, the conditions just mentioned are not favorable to their best development.

Results at Hays, Kans.[1]

The Kherson and Sixty-Day varieties have been included in the experiments conducted at the Hays (Kans.) Branch Experiment Station since 1908, but comparable data are available from these experiments only since 1913. The annual and average yields of these and of two other varieties of oats grown at Hays during the four years from 1913 to 1916, inclusive, are given in Table XXXIX.

TABLE XXXIX.—*Annual and average yields of selections of the Kherson and Sixty-Day and of two other varieties of oats grown at the Hays (Kans.) Branch Experiment Station for three or more years in the 4-year period from 1913 to 1916, inclusive.*

[Data obtained in cooperation with the Kansas Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).					
		1913	1914	1915	1916	Average.	
						1914 to 1916	1913 to 1916
Early yellow:							
Albion (Iowa No 103, white)	729	5.8	17.2	12.1	8.0	12.4	10.8
Sixty-Day selection	626	6.4	14.0	11.7	5.8	10.5	9.5
Early red:							
Burt × Sixty-Day hybrid	727	5.8	18.4	22.6	12.4	17.8	14.8
Burt[1]	....	....	22.5	8.9	11.7	14.4	....

[1] A commercial lot of Burt; not a pure line.

It will be noted from Table XXXIX that very poor yields were obtained at Hays; in fact, so poor that the crop is evidently not a profitable one. From the few data shown it appears that the Burt will outyield the Kherson and Sixty-Day in this section. The best yield at the station was produced by a Burt × Sixty-Day hybrid which is not yet commercially grown.

Results at Amarillo, Tex.[2]

The Kherson, the Sixty-Day, and the Seventy-five Day oats all have been included in the varietal experiments at Amarillo since 1906. Several selections of the Sixty-Day variety also have been included for shorter periods. The annual and average yields of these strains and of six other varieties and selections are shown in Table XL.

The data shown in Table XL indicate that the early red varieties, Red Algerian, Red Rustproof, and Burt, at Amarillo outyield the Kherson and Sixty-Day on the average from 2 to 4 bushels per acre. The average yield of the best red strain in the eleven years from 1906 to 1916, inclusive, is 20.6 bushels, compared with 18.9 bushels for the best Sixty-Day. The average yield of two strains of Red Algerian, one of Burt, and one of Red Rustproof range only from 19.8 to 20.6 bushels.

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[1] Compiled from unpublished reports of Mr. F. A. Kiene, jr., formerly assistant agronomist in charge of cereal experiments at the Hays Branch Experiment Station, to the Office of Cereal Investigations.

[2] Data to and including 1911 were published in U. S. Department of Agriculture, Bureau of Plant Industry Bulletin 283 (31). Data from 1912 to 1917 have been compiled from unpublished reports of Mr. John F. Ross, the superintendent of the Amarillo Cereal Field Station, to the Office of Cereal Investigations.

TABLE XL.—*Annual and average yields of five early yellow and six other varieties of oats grown at the Amarillo (Tex.) Cereal Field Station during six or more years in the 11-year period from 1906 to 1916, inclusive.*[1]

Group and variety.	C. I. No.	Yield per acre (bushels).													
		1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	Average.		
													1906 to 1916	1911 to 1916	1907 to 1915
Early yellow:															
Sixty-Day	[2] 165	21.1	20.9	30.6	19.7	5.8	8.8	24.1	11.6	28.4	23.1	13.9	18.9	18.3	19.2
Do	[3] 165	....	24.4	32.5	16.3	3.9	11.7	22.5	10.0	29.1	20.3	....	....	....	19.0
Sixty-Day selection 4P4	789	....	....	....	....	....	12.5	26.2	13.2	28.7	20.3	14.7	....	19.3	....
Seventy-five Day	337	12.4	22.7	24.1	18.1	4.5	17.0	22.8	11.6	29.4	20.6	11.6	17.7	18.8	19.0
Kherson	459	11.5	15.2	20.6	19.1	4.5	16.7	24.1	6.2	29.4	18.1	10.8	16.0	17.6	17.1
Early red:															
Burt	[4] 293	13.3	16.2	23.4	16.6	8.0	18.7	21.6	16.9	40.3	31.1	[5] 11.9	19.8	23.4	21.4
Burt selection	293-VI.	....	10.3	23.4	12.8	9.3	20.6	20.9	14.1	40.0	30.3	....	....	....	20.2
Red Algerian	[6] 286	16.0	17.6	38.1	17.8	11.4	17.9	26.3	7.7	41.5	24.9	7.5	20.6	21.0	22.6
Do	[7] 286	10.6	20.4	30.3	19.1	10.9	16.3	28.4	8.7	45.0	23.4	7.3	20.0	21.5	22.5
Red Rustproof	458	19.8	19.3	32.7	9.7	9.0	17.8	25.9	11.9	39.4	29.4	10.0	20.4	22.4	21.7
Do	487	....	14.7	31.9	17.8	10.1	6.6	27.5	8.7	43.1	24.7	8.9	....	19.9	20.6

[1] Data to and including 1911 were previously published in Bur. Plant Indus. Bul. 283 (31).
[2] S. P. I. No. 5938.
[3] S. P. I. No. 17720.
[4] S. P. I. No. 15856.
[5] Yield from 6-peck rate in rate-of-seeding test.
[6] S. P. I. No. 12133.
[7] S. P. I. No. 15858.

Conclusions.

The average yield of the leading variety in each group at the stations included in the southern Great Plains is shown graphically in figure 12.

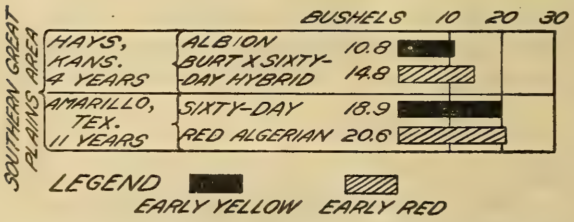

FIG. 12.—Diagram showing the average yields, in bushels per acre, of the highest yielding variety of each of several groups of oats at two agricultural experiment stations in the southern Great Plains area during the periods of years indicated.

The data obtained at both Hays, Kans., and Amarillo, Tex., show that the early red varieties, Burt, Red Rustproof, and Red Algerian, are the best to grow in the southern Great Plains area. While the yields of the Kherson and Sixty-Day have been somewhat lower than those of the Burt and Red Rustproof, they doubtless are the next best varieties to grow.

RESULTS IN THE WESTERN BASIN AND COAST AREAS.

The western basin and coast areas include that portion of the United States lying west of the Rocky Mountains. The growing of oats and other small grains in this region is confined mostly to the less arid districts. The results of experiments under irrigation are reported in another section of this bulletin. The principal grain-growing districts are the Great Basin, the Snake River Basin, the Columbia Basin, and the central valleys of California. These include parts of the States of Utah, Nevada, California, Idaho, Oregon, and Washington.

Varietal experiments with the Kherson and the Sixty-Day and other varieties of oats have been conducted at the following stations: Nephi, Utah; Aberdeen, Idaho; Burns and Moro, Oreg.; and Chico, Calif. At each of these points, except Chico, the work has been conducted cooperatively by the United States Department of Agriculture and the respective State agricultural experiment station. At Chico the work has been conducted in cooperation with the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry. The experiments at Pullman and Puyallup, Wash., were conducted and reported independently by the Washington Agricultural Experiment Station. The results of cereal experiments at the Oregon Agricultural Experiment Station at Corvallis have never been published.

The climate of these basins and valleys, except that of Puget Sound, is exceedingly dry, varying from semiarid to arid. Table XLI contains a record of the altitude, annual and seasonal precipitation, mean temperatures for June, July, and August, and the general soil type at each of the seven stations in this section.

As a rule, the precipitation of these sections is markedly low, and most of it occurs during the autumn, winter, and spring months. This is the reverse of the conditions in the Great Plains area, where the greater portion of the precipitation occurs during the summer months, the growing season. For this reason winter rather than spring grains are grown in this section.

TABLE XLI.—*Altitude, average annual and seasonal precipitation, mean seasonal temperatures, and general soil types at seven experiment stations in the western basin and coast areas.*

Station.	Altitude.	Climatological data.						General soil type.
		Length of record.	Average precipitation.		Mean temperature (°F.).			
			Annual.	Seasonal.[1]	June.	July.	August.	
	Feet.	*Years.*	*Inches.*	*Inches.*				
Nephi, Utah	6,000	18	13.44	3.75	....	....	....	Sandy clay loam.
Aberdeen, Idaho	4,400	6	9.20	4.16	....	....	....	Sandy clay loam (lava ash).
Burns, Oreg.	4,100	12	11.74	2.67	[2]57.4	[2]65.8	[2]64.7	Silt loam to very fine sandy loam.
Moro, Oreg.	1,800	11	11.35	3.70	[5]59.6	[c]67.8	[3]67.4	Silt loam.
Pullman Wash.	....	[4]17	22.51	6.17	58.4	66.8	65.6	
Puyallup, Wash.	....	[5]25	43.01	8.21	59.4	63.4	63.0	Clay ("Upland shot").
Chico, Calif.	189	40	23.39	....	77.1	83.9	81.5	Sandy loam.

[1] For months of April to June, inclusive, at Nephi, Utah; April to July, inclusive, at Aberdeen, Idaho, Burns, Oreg., Pullman and Puyallup, Wash.; and March to July, inclusive, at Moro, Oreg.

[2] Sixteen-year average.

[3] Five-year average.

[4] Data recorded at Moscow, Idaho, about ten miles east of Pullman, Wash.; altitude at Moscow 2,748 feet.

[5] Data recorded at Tacoma, 10 miles northwest of Puyallup, Wash.

The altitude of Nephi, Utah (6,000 feet), is the highest of the stations here discussed, and that of Chico, Calif. (189 feet), is the lowest. Aberdeen and Burns each have an altitude of more than 4,000 feet. At the Burns station in the Harney Valley frost frequently occurs during the summer months. The advantage of early varieties of oats over midseason or late varieties is apparent under such conditions. The summers are very warm and evaporation is fairly high, but wind velocities are low in most of these sections. The soils for the most part vary from sandy clay to silt loams.

Results in Utah.[1]

The Sixty-Day oat has been included in the cooperative varietal experiments at Nephi since the work was started at that station in 1908. The Kherson variety was grown only during the years 1909 to 1911, inclusive. Two selections of Kherson from the Iowa station were added to the experiments in 1916. In addition to these, only a few other varieties have been included in the tests at Nephi. The annual and average yields of those varieties which have been grown during three or more years in the 10-year period from 1908 to 1917, inclusive, are presented in Table XLII.

TABLE XLII.—*Annual and average yields of the Sixty-Day, the Kherson, the Richland, the Albion, and four other varieties of oats grown at the Nephi (Utah) substation during two or more years in the 10-year period from 1908 to 1917, inclusive.*

[Data obtained in cooperation with the Utah Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).												
		1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Average.		
												1908 to 1917	1910 to 1917	1916 and 1917
Early yellow:														
Sixty-Day	165	16.0	15.0	a2.8	2.8	15.3	6.3	30.6	36.1	10.6	19.4	15.5	15.5	15.0
Kherson	459	.....	16.6	0.6	5.9	.....	.....	.....	.....	.....	.....	.....	.....	.....
Albion (Iowa No. 103, white)	729	.....	.....	.....	.....	.....	.....	.....	.....	15.6	21.7	.....	.....	18.7
Richland (Iowa No. 105)	787	.....	.....	.....	.....	.....	.....	.....	.....	16.6	20.0	.....	.....	18.3
Midseason yellow:														
Giant Yellow (side)	568	9.7	16.3	6.9	12.2	21.4	12.8	22.5	31.3	.....	.....	.....	.....	.....
Midseason white:														
Swedish Select	134	[3]44.1	[2]15.4	[4]6.2	8.8	24.1	13.1	30.7	[5]39.1	[5]15.8	[5]8.6	20.6	18.3	12.2
Roosevelt	752	.....	.....	10.9	[6]11.5	26.6	11.6	35.0	30.3	15.9	2.8	.....	18.1	9.4
Midseason black:														
Black American	549	15.6	15.6	8.4	11.6	25.3	13.5	29.4	[5]42.5	[5]16.9	[5]14.7	19.4	20.3	15.8
Winter:														
Boswell (black)	480	.....	16.0	5.3	38.1	11.1	(7)	[8]44.4	[5]56.9	9.7	20.0	.....	23.2	14.9

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[1] Data obtained cooperatively by the Utah Agricultural Experiment Station and the Bureau of Plant Industry. The data previous to 1917 have been reported in the following publications: U. S. Department of Agriculture Bulletin 30 (8); U. S. Department of Agriculture Farmers' Bulletin 883 (20); and Utah Agricultural Experimental Station Circular 21 (16).

[2] Average yield of five plats.

[3] Grown on land which has been fallow for two years. All the other varieties were grown in 1908 on plats which had produced wheat the previous season.

[4] Average yield of four plats.

[5] Yield of selection, original stocks not grown.

[6] Average yield of three plats.

[7] Completely winterkilled.

[8] From 6-peck rate in rate-of-seeding test.

The data given in Table XLII show that the midseason white varieties have outyielded the early yellow ones at Nephi in a series of years. The table also shows that in the 8-year period from 1910 to 1917, inclusive, the Boswell Winter oat has outyielded all others, despite the fact that in 1913 this variety entirely winterkilled.

In the two years (1916 and 1917) in which they have been tested, Albion and Richland, the two selections from Kherson, have outyielded all others at Nephi and appear to be of considerable promise for central Utah.

Results in Idaho.[1]

The Kherson and Sixty-Day varieties have been included in the dry-land experiments at Aberdeen, Idaho, since 1911, when cooperative cereal investigations were begun at that station. Only two other varieties, Swedish Select and a white selection from an oat known as "Rustless," have been included. These latter were grown only during the years 1915, 1916, and 1917. Table XLIII shows the annual and average yields of these varieties at Aberdeen.

Table XLIII.—*Annual and average yields of the Kherson, the Sixty-Day, and two other varieties of oats grown at the Aberdeen (Idaho) substation during three or more years in the 5-year period from 1913 to 1917, inclusive.*

[Data obtained in cooperation with the Idaho Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).						
		1913	1914	1915	1916	1917	Average.	
							1913 to 1917	1915 to 1917
Early yellow:								
Sixty-Day	165	47.5	40.3	[1]28.1	16.8	28.7	32.3	24.5
Kherson	723	38.1	32.5	26.4	16.2	29.3	28.5	24.0
Midseason white:								
"Rustless" selection (Iowa No. 444)	724	....	....	24.8	19.2	28.7	....	24.2
Swedish Select	134	....	....	18.2	15.0	19.3	....	17.5

[1] Average of two plats.

The early yellow varieties, Kherson and Sixty-Day, have decidedly outyielded the Swedish Select, a midseason white variety. The superiority of the early varieties has been so marked in a practical as well as in an experimental way that it has not been thought worth while to include varieties representing other types in the experiments on dry land.

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[1] Compiled from unpublished reports of Mr. L. C. Aicher, the superintendent of the Aberdeen substation, to the Office of Cereal Investigations. Data obtained previous to 1916 are summarized in U. S. Department of Agriculture Farmers' Bulletin 769 (1).

Results in Oregon.

RESULTS AT BURNS.[1]

The Kherson and Sixty-Day oats have been included in the cooperative varietal experiments at Burns since they were begun in 1913. Two selections of the Sixty-Day variety have been grown since 1913, and an additional one since 1914. The annual and average yields of these and of three other varieties which have been grown during the 5-year period from 1913 to 1917, inclusive, are presented in Table XLIV.

TABLE XLIV.—*Annual and average yields of three early yellow and four other varieties of oats grown at the Harney Branch Experiment Station, Burns, Oreg., during the 5-year period from 1913 to 1917, inclusive.*

[Data obtained in cooperation with the Oregon Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).					
		1913	1914	1915	1916	1917	Average, 1913 to 1917.
Early yellow:							
Kherson	459	60.7	16.9	22.3	43.1	10.5	30.7
Sixty-Day selection	625	55.0	19.8	21.9	42.7	11.2	30.1
Sixty-Day selection 4P4	789	....	19.7	19.2	43.9	10.2	....
Midseason white:							
"Rustless" selection (Iowa No. 444)	724	56.2	11.2	49.4	45.0	9.3	34.2
Silvermine	720	63.7	14.0	25.0	43.1	9.3	31.0
Swedish Select	134	33.1	12.8	29.4	43.7	3.8	24.6
Midseason black:							
Black American	549	61.9	12.3	26.4	28.5	1.9	26.2

A selection from a variety at the Iowa station known as Rustless, Iowa No. 444 and C. I. No. 724, somewhat similar to Silvermine, has been the highest yielder in the 5-year period at Burns, with an average yield of 34.2 bushels, compared with 31.0, 30.7, 30.1, and 24.6 bushels from Silvermine, Kherson, Sixty-Day (C. I. No. 625), and Swedish Select, respectively.

While these experiments have not been of sufficient duration to warrant definite conclusions, indications are that the Silvermine type is slightly better than the Sixty-Day to grow in the Harney Valley, except where early maturity is a distinct advantage.

RESULTS AT MORO.[2]

The Kherson and Sixty-Day oats have been included in the cooperative varietal experiments at Moro since the cereal work was begun there in 1911. In addition, three selections from the Sixty-Day, two selections from the Kherson, and seven other varieties and selections of oats have been grown at Moro for two or more years in the 7-year period from 1911 to 1917, inclusive. The annual and average yields of these are presented in Table XLV.

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[1] Compiled from unpublished annual reports of Mr. L. R. Breithaupt, formerly superintendent of the Harney Branch Experiment Station, to the Office of Cereal Investigations. Data obtained previous to 1917 are summarized in U. S. Department of Agriculture Farmers' Bulletin 800 (6).

[2] Data obtained cooperatively by the Oregon Agricultural Experiment Station and the Bureau of Plant Industry. Data previous to 1917 were published in U. S. Department of Agriculture Bulletin 498 (37) and in Oregon Agricultural Experiment Station Bulletin 144 (38).

TABLE XLV.—*Annual and average yields of six early yellow and eight other varieties and selections of oats grown at the Eastern Oregon Dry-Farming Branch Experiment Station (at Moro) during two or more years in the 7-year period from 1911 to 1917, inclusive.*

[Data obtained in cooperation with the Oregon Agricultural Experiment Station.]

Group and variety.	C.I. No.	Yield per acre (bushels).									
		1911	1912	1913	1914	1915	1916	1917	Average.		
									1911 to 1917	1914 to 1917	1916 and 1917
Early yellow:											
Kherson	459	28.9	39.6	43.6	54.2	52.6	84.4	37.5	48.7	57.2	61.0
Sixty-Day	165	18.7	40.0	47.8	52.3	57.8	83.8	40.0	48.6	58.5	61.9
Sixty-Day selection	789	11.2	37.1	66.5	33.7	......	......	......	......	......	......
Do	165-1-1	......	......	45.6	61.9	57.1	......	......	......	......	......
Do	165-1	......	......	......	65.6	57.2	80.3	37.2	......	60.1	58.8
Albion (Iowa No. 103, white)	729	......	......	......	......	......	71.5	38.8	......	......	55.2
Richland (Iowa No. 105)	787	......	......	......	......	......	86.9	40.6	......	......	63.8
Midseason white:											
Swedish Select	134	13.5	37.0	40.7	37.2	47.0	105.9	28.8	44.3	54.7	67.4
Siberian	635	30.8	35.6	53.7	37.0	58.3	99.6	29.1	49.2	56.0	64.4
Canadian	444	17.1	38.4	46.4	45.2	48.9	68.8	28.4	41.9	47.8	48.6
Shadeland Climax	681	......	44.3	36.5	35.1	55.3	91.0	26.3	......	51.9	58.7
Midseason black:											
Black American	549	35.1	35.1	42.5	33.8	43.4	97.1	......	......	......	......
Late white (side):											
Storm King	522-1	......	......	46.2	35.6	63.0	......	......	......	......	......
White Russian	636	13.7	28.1	30.0	......	......	......	......	......	......	......

The results at Moro, as shown in Table XLV, are similar to those obtained at Burns. They indicate that there is little choice between the early yellow and the midseason white varieties for growing in the Columbia Basin. The five varieties which have been grown during the entire 7-year period are Siberian, Kherson, Sixty-Day, Swedish Select, and Canadian, with average yields of 49.2, 48.7, 48.6, 44.3, and 41.9 bushels, respectively. In the 4-year period, 1914 to 1917, inclusive, a selection from Sixty-Day, 165-1, leads with an average yield of 60.1 bushels, which is 4.1 bushels higher than that of the Siberian, the best midseason variety, and 1.6 bushels higher than that of the original Sixty-Day. The earlier maturity of the Kherson and Sixty-Day varieties also must be taken into consideration, as earliness is frequently a decided advantage in this section of the country.

Results in Washington.

RESULTS AT PULLMAN.

The annual and average yields of the Sixty-Day and four other varieties of oats grown at the Washington Agricultural Experiment Station at Pullman (33) in 1914 and 1915 are shown in Table XLVI.

TABLE XLVI.—*Annual and average yields of the Sixty-Day and four other varieties of oats grown at the Washington Agricultural Experiment Station (at Pullman) in 1914 and 1915.*

[Data compiled from Washington Agricultural Experiment Station Bulletin 129 (33).]

Group and variety.	Washington No.	Yield per acre (bushels).		
		1914	1915	Average.
Early yellow:				
Sixty-Day	661	69.6	84.9	77.3
Midseason white:				
Abundance	759	87.4	76.1	81.8
Banner	764	80.2	76.3	78.3
Swedish Select	662	75.4	81.0	78.2
Sparrowbill[1]	741	76.0	77.0	76.5

[1] Not true Sparrowbill, which is a side oat; probably Danish.

The few data presented in Table XLVI indicate that there is little choice between the early yellow and the midseason white varieties for growing in the Palouse district of eastern Washington. The average yields of the varieties in the two groups are about the same.

RESULTS AT PUYALLUP.

The average yields of the Sixty-Day and eight other varieties of oats grown from spring seeding at the Western Washington Agricultural Experiment Station at Puyallup (40, p. 11–12) in the 3-year period from 1914 to 1916, inclusive, are shown in Table XLVII.

TABLE XLVII.—*Average yields of the Sixty-Day and eight other varieties of oats grown at the Western Washington Experiment Station (at Puyallup) during 1914, 1915, and 1916.*

[Data compiled from Washington Agricultural Experiment Station Monthly Bulletin for April, 1917 (40, pp. 11–12).]

Group and variety.	Yield per acre.	Group and variety.	Yield per acre.
	Bushels.		*Bushels.*
Early yellow:		Midseason white—Continued.	
Sixty-Day	51.7	White Bonanza	54.7
Midseason white:		Canadian	53.4
Swedish Select	63.2	Midseason black:	
Big Four	59.8	Black	56.5
Ligowo selection (Minn. No. 281)	59.5	Late white (side):	
Swedish Select (Shadeland Climax)	56.7	Sparrowbill	59.4

It is realized that the data contained in Table XLVII are too meager to be conclusive. However, they indicate that the best midseason varieties probably will outyield the Sixty-Day under western Washington conditions. The high rainfall and comparatively cool growing season of the Puget Sound district naturally favor the larger midseason varieties.

Results in California.[1]

The Sixty-Day oat has been included in the cooperative varietal experiments at the Plant Introduction Garden at Chico, Calif., since they were begun in 1910. The annual and average yields of the Sixty-Day and four other varieties grown during four or more years of the 7-year period from 1910 to 1916, inclusive, are shown in Table XLVIII. Owing to the lack of land no varieties of oats were grown at Chico in 1917.

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[1] Data from unpublished annual reports of Mr. E. L. Adams, formerly assistant agronomist in charge of cereal experiments at the Plant Introduction Garden, to the Office of Cereal Investigations.

TABLE XLVIII.—*Annual and average yields of the Sixty-Day and four other varieties of oats grown at the Plant Introduction Garden at Chico, Calif., for five or more years in the 7-year period from 1910 to 1916, inclusive.*[1]

[Data obtained in cooperation with the Office of Foreign Seed and Plant Introduction.]

Group and variety.	C. I. No.	Yield per acre (bushels).							
		1910	1911	1913	1914	1915	1916	Average.	
								1910 to 1916	1913 to 1916
Early yellow:									
Sixty-Day	165	31.0	52.3	[2] 43.8	39.2	20.9	26.3	35.6	32.6
Early red:									
Red Rustproof (Calif. Red)	616	24.3	65.6	41.8	43.3	27.3	28.5	38.5	35.2
Midseason white:									
Danish Island	519	......	......	35.3	51.4	24.5	20.4	......	32.9
Silvermine	520	......	......	23.0	38.5	17.0	21.3	......	25.0
Winter:									
Winter Turf (Dewey)	180	......	88.7	36.3	36.7	24.8	23.6	......	30.4

[1] Yields of oats not comparable in 1912; plats were badly infested with wild oats and other weeds.

[2] Average of four check plats.

Reference to Table XLVIII shows that in the six years, 1910, 1911, and 1913 to 1916, inclusive, the Red Rustproof has outyielded the Sixty-Day by 2.9 bushels at Chico. In the 4-year period from 1913 to 1916, inclusive, the difference is about the same in favor of the Red Rustproof. In this period the Danish Island also has slightly outyielded the Sixty-Day. These tests indicate that the Red Rustproof is to be preferred to all others in the central valleys of California. This is in accordance with the experience of farmers, and as a consequence the Red Rustproof is the variety commonly grown in California, where it is known as California Red, or Common California.

Conclusions.

The average yield of the leading variety in each group at the stations included in the western basin and coast areas is shown graphically in figure 13.

The results presented in Tables XLII to XLVIII, inclusive, show that the early yellow varieties, Kherson and Sixty-Day, are high yielders under dry-land conditions at all the stations west of the Rocky Mountains with the exception of Nephi, Utah. The climatic conditions at this station seem to favor the midseason varieties. In western Washington (Puyallup) the rainfall is too heavy for it to be classed as a dry-land section. At the other four stations usually one or more of the midseason white varieties have slightly outyielded the Kherson and Sixty-Day.

The ability of the Sixty-Day and Kherson varieties to yield as well as the midseason varieties and to mature 10 days to two weeks earlier gives a distinct advantage, and they therefore are to be recommended.

RESULTS UNDER IRRIGATION.

The Kherson and Sixty-Day oats are not extensively grown under irrigation. As a rule, the larger and later maturing varieties are grown, as they usually yield better. However, where the growing season is short the early varieties are desirable and often yield surprisingly well. Cooperative varietal experiments with Kherson and Sixty-Day oats have been conducted under irrigation at Newell, S. Dak., and Aberdeen, Idaho, for six and five years, respectively. In addition, results of experiments with Kherson and Sixty-Day oats under irrigation conducted independently by the Nevada and Montana agricultural experiment stations at Reno and Bozeman and at the Gooding (Idaho) substation are presented herewith.

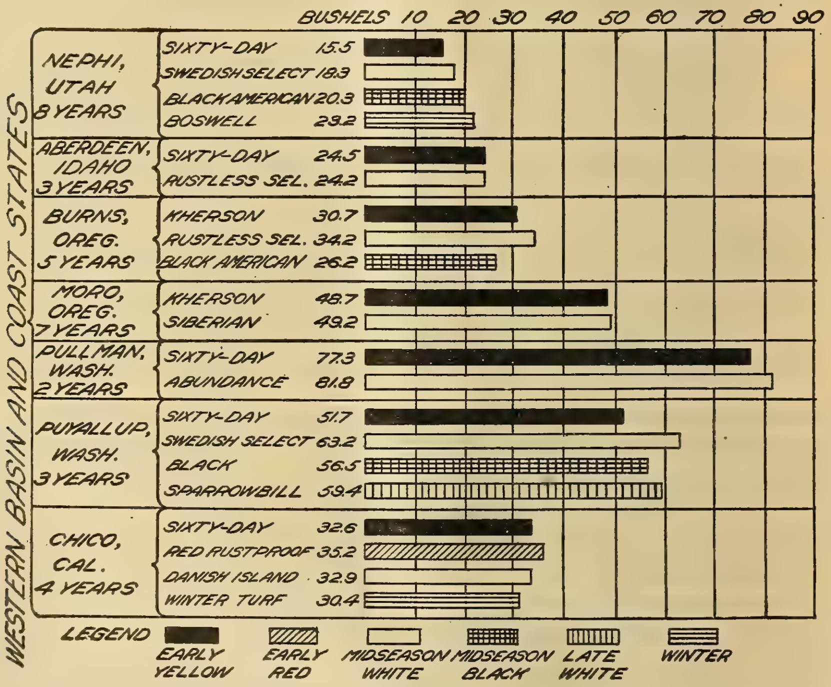

FIG. 13.—Diagram showing the average yields, in bushels per acre, of the highest yielding variety of each of several groups of oats at seven agricultural experiment stations in the western basin and coast areas during the periods of years indicated.

The general physical conditions at these stations are shown in Table XLIX.

Under irrigation, precipitation naturally ceases to be a limiting factor in crop production, and because of the availability of an ample water supply the period of plant growth is lengthened somewhat. As the oat plant requires large quantities of water for its best development, high yields of grain of excellent quality usually are produced in irrigated districts.

TABLE XLIX.—*Altitude, average annual and seasonal precipitation, mean seasonal temperatures, and general soil types at five experiment stations in the northern Great Plains and western basin areas.*

Station.	Altitude.	Climatological data.						General soil type.
		Length of record.	Average precipitation.		Mean temperature (°F.).			
			Annual.	Seasonal.[1]	June.	July.	Aug.	
	Feet.	*Years.*	*Inches.*	*Inches.*				
Newell, S. Dak.	2,950	9	13.98	9.20	65.0	72.0	69.0	Sandy loam.
Bozeman, Mont.	4,700	35	18.60	10.97	[2] 58.7	[2] 65.8	[2] 64.3	
Aberdeen, Idaho.	4,400	6	9.80	4.84	....	....	....	Sandy clay loam, lava ash.
Gooding, Idaho.	3,600	7	9.20	2.92	62.3	70.1	68.5	Medium clay loam.
Reno, Nev.	4,532	22	8.65	2.15	62.4	69.8	69.2	

[1] April to August, inclusive.

[2] Twenty-nine year average.

Results under Irrigation in South Dakota.

The Sixty-Day oat has been included in varietal experiments conducted under irrigation at Newell since 1912. The annual and average yields of the Sixty-Day and of three other varieties which have been grown during the 6-year period from 1912 to 1917, inclusive, together with the yields of one variety grown during three years, are given in Table L.

TABLE L.—*Annual and average yields of the Sixty-Day and four other varieties of oats grown under irrigation at the Belle Fourche Experiment Farm, Newell, S. Dak., during three or more years in the 6-year period from 1912 to 1917, inclusive.*

[Data obtained in cooperation with the Office of Western Irrigation Agriculture and since 1912 with the South Dakota Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).							
		1912	1913	1914	1915	1916	1917	Average.	
								1912 to 1917	1914 to 1917
Early yellow:									
Sixty-Day	165	25.0	47.1	32.5	34.0	28.8	51.5	36.5	36.7
Midseason white:									
Swedish Select	134	35.2	33.0	41.6	46.5	36.9	54.6	41.3	44.9
Canadian	444	31.2	39.3	42.4	44.7	25.2	65.8	41.4	44.5
Unnamed[1]	778	....	....	50.7	51.8	37.4	57.8	....	49.4
Late white (side):									
White Russian	551	41.4	33.7	48.6	52.8	42.1	56.2	45.8	49.9

[1] Similar to Swedish Select; original seed supposed to have been obtained from Norway.

The results shown in Table L decidedly favor the midseason and late varieties for growing under irrigated conditions similar to those at Newell. Of the four varieties under experiment during the full 6-year period the White Russian leads with an average yield of 45.8 bushels, as compared with 36.5 bushels for the Sixty-Day, a difference of nearly 10 bushels. In the 4-year period from 1914 to 1917, inclusive, the White Russian and a local variety similar to Swedish Select lead with average yields of 49.9 and 49.4 bushels, respectively, as compared with an average of 36.7 bushels for the Sixty-Day during the same period.

Results under Irrigation in Montana.

The average yields of the Kherson, the Sixty-Day, and eight other varieties of oats grown under irrigation at the Montana Agricultural Experiment Station at Bozeman (2) in the 5-year period from 1907 to 1911, inclusive, are shown in Table LI.

TABLE LI.—*Average yields of the Kherson, the Sixty-Day, and eight other varieties of oats grown under irrigation at the Montana Agricultural Experiment Station (at Bozeman) during the 5-year period from 1907 to 1911, inclusive.*

[Data compiled from Montana Agricultural Experiment Station Bulletin 84 (2).]

Group and variety.	Yield per acre.	Group and variety.	Yield per acre.
Early yellow:	*Bushels.*	Midseason white—Continued.	*Bushels.*
Sixty-Day	73.9	Siberian	98.3
Kherson	82.0	Swedish Select	97.9
Early white:		Late white (side):	
Early Champion	70.9	Sparrowbill	93.1
Midseason white:		Tartar King	90.0
Banner	102.3	White Tartar	80.2
Danish	100.0		

Reference to Table LI shows that both the midseason and the late varieties have materially outyielded the Sixty-Day and Kherson at Bozeman on irrigated land. Banner, the highest yielding midseason oat, has exceeded the Kherson and the Sixty-Day in average yield by about 20 and 30 bushels, respectively, during the 5-year period. As indicated by these results, it is usually more profitable to grow the midseason and late varieties under conditions similar to those at Bozeman, unless for some reason an early-maturing oat is required.

In a recent publication (3, p. 166–167) the Montana Agricultural Experiment Station reports that Ontario A. C. No. 72, a selection from Siberian imported from Canada, yields best under irrigation. During the past four years it has averaged 119.4 bushels per acre. Other varieties showing high average yields under irrigation were Myrick, Silvermine, Belyak, and Banner with yields of 114.9, 113.9, 110.1, and 109.6 bushels per acre, respectively.

Results under Irrigation in Idaho.

RESULTS AT ABERDEEN.[1]

The Kherson and Sixty-Day oats have been included in the cooperative varietal experiments conducted under irrigation at Aberdeen, Idaho, since 1913, when experimental work was begun at that station. Albion and Richland, two selections of Kherson from the Iowa station, were added to the tests in 1916. In Table LII the annual and average yields of these and seven other varieties grown at Aberdeen during two or more years in the 5-year period from 1913 to 1917, inclusive, are presented.

TABLE LII.—*Annual and average yields of the Kherson, Sixty-Day, Richland, Albion, and seven other varieties of oats grown under irrigation at the Aberdeen (Idaho) substation during two or more years in the 5-year period from 1913 to 1917, inclusive.*

[Data obtained in cooperation with the Idaho Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).						
		1913	1914	1915	1916	1917	Average.	
							1913 to 1917	1916and 1917
Early yellow:								
Kherson	423	88.7	110.0	160.2	119.2	116.2	118.9	117.7
Sixty-Day	165	103.0	101.4	161.9	98.5	90.6	111.1	94.6
Albion (Iowa No. 103, white)	729	....	....	....	106.2	123.1	....	114.7
Richland (Iowa No. 105)	787	....	....	....	114.2	109.3	....	111.8
Midseason yellow:								
Golden Rain	493	126.2	98.8	153.5	111.0	110.6	120.0	110.8
Midseason white:								
Early Mountain	754	103.8	120.3	158.5	111.0	111.8	121.1	111.4
Silvermine	720	102.2	113.4	163.6	106.2	109.3	118.9	107.8
Swedish Select	134	[1]104.2	97.1	163.6	93.7	102.5	112.2	98.1
"Rustless" selection	724	103.8	120.3	158.5	[2]68.7	120.6	114.4	94.7
Lincoln	756	73.1	115.6	163.6	96.2	98.1	109.3	97.2
Late white (side):								
Tartar King	759	106.2	100.5	123.1	....	....	....	....

[1] Average of two check plats.
[2] Yields not comparable, due to poor stand resulting from seed treatment for smut.

Reference to Table LII shows that of the eight varieties which have been grown for five years the Early Mountain and Golden Rain only slightly outyielded the Kherson, with the Silvermine equaling the Kherson in yield. All of the midseason varieties except Lincoln, however, have outyielded the Sixty-Day in that period. In the 2-year period, 1916 and 1917, the Kherson has outyielded all others. The Albion (Iowa No. 103), a white selection from Kherson, has averaged only 3 bushels less. Indications are that this new oat is of considerable promise for irrigated conditions in southern Idaho.

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[1] The data here presented are from unpublished reports of Mr. L. C. Aicher, the superintendent of the Aberdeen substation, to the Office of Cereal Investigations.

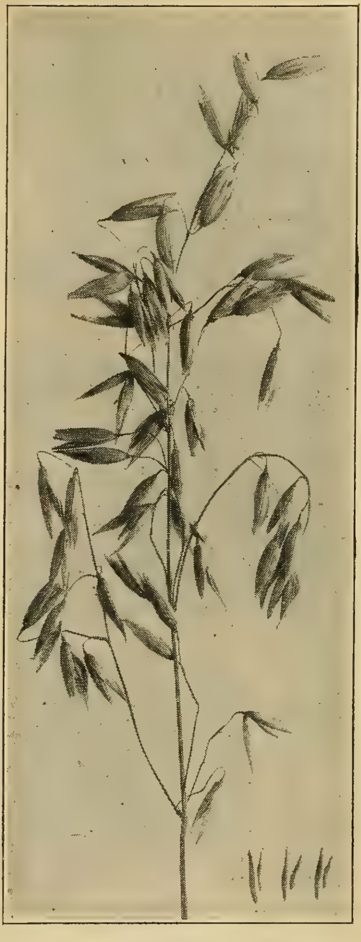

FIG. 14.—Panicle and spikelets of a midseason yellow variety of oats, Golden Rain.

Tartar King, the one late side variety which has been tested, has fallen decidedly below both the early and midseason varieties in average yield per acre and has been discarded. A panicle and spikelets of Golden Rain, a midseason yellow variety of oats, are shown in figure 14.

RESULTS AT GOODING.

Average yields of the Kherson, the Sixty-Day, and eight other varieties of oats grown during one or more years in the 6-year period from 1910 to 1916, inclusive, under irrigation at Gooding, Idaho (48), are shown in Table LIII.

Unfortunately, the Kherson and the Sixty-Day were included in the experiments at Gooding during only one year, and as a result sufficient data on these varieties are not available to justify drawing definite conclusions regarding their value. The data shown in Table LIII indicate, however, that the best midseason white varieties will probably outyield them in most years. The contradictory results obtained here and at Aberdeen are perhaps due to the lower altitude at Gooding, with the resultant longer and warmer growing season.

TABLE LIII.—*Average yields of the Kherson, the Sixty-Day, and eight other varieties of oats grown under irrigation at the Gooding (Idaho) substation during one or more years in the 6-year period from 1910 to 1916, inclusive.*

[Data compiled from Idaho Agricultural Experiment Station Bulletin 93 (48).]

Group and variety.	Length of record.	Yield per acre.	Group and variety.	Length of record.	Yield per acre.
Early yellow:	*Years.*	*Bushels.*	Midseason white—Continued.	*Years.*	*Bushels.*
Kherson	1	71.1	Victory	6	86.6
Sixty-Day	1	61.0	Danish Island	6	86.6
Midseason yellow:			Lincoln	6	86.2
Golden Rain	6	83.4	Swedish Select	5	96.6
Midseason white:			Wisconsin Pedigreed No. 1	4	96.5
Colorado No. 37	6	88.2	Late white (side):		
Big Four	6	87.4	White Russian	5	82.4

Results under Irrigation in Nevada.

The annual and average yields of the Kherson, the Sixty-Day, and several other varieties of oats grown under irrigation at the Nevada Agricultural Experiment Station at Reno (22, p. 31–34) during two or more years in the 3-year period from 1914 to 1916, inclusive, are shown in Table LIV.

TABLE LIV.—*Annual and average yields of the Kherson, Sixty-Day, and nine other varieties of oats grown at the Nevada Agricultural Experiment Station (at Reno) during two or more years of the 3-year period from 1914 to 1916, inclusive.*

[Data compiled from Nevada Agricultural Experiment Station Bulletin 89 (22, p. 31–34).]

Group and variety.	Yield per acre (bushels).				
	1914	1915	1916	Average.	
				1914 to 1916	1915 and 1916
Early yellow:					
Kherson	44.5	51.8	31.1	42.5	41.5
Sixty-Day	21.7	29.5	....	....	....
Midseason white:					
Big Four	25.4	59.2	50.4	45.0	54.8
Garton No. 572[1]	20.7	69.5	41.9	44.0	55.7
Danish	35.1	52.4	46.7	44.7	49.6
Siberian	24.6	64.5	45.0	44.7	54.8
Midseason black:					
Black American[2]	....	57.6	60.5	....	59.1
Missouri Black[3]	12.6	63.1	39.9	38.5	51.5
Late white (side):					
Sparrowbill	35.8	52.4	....	....	....

[1] Probably identical with Lincoln. [2] Cereal Investigations No. 549. [3] Probably Monarch.

The data shown in Table LIV are the yields from very small plats, not replicated sufficiently to eliminate a high percentage of experimental error. The midseason varieties outyielded the Kherson and the Sixty-Day by a sufficiently wide margin, however, to indicate that they are to be preferred for growing under irrigation in western Nevada, although climatic conditions appear to favor early oats.

In reporting his results, Professor Knight states:

> The lack of humidity together with the intense heat of the sun during the ripening period often causes the panicles to blast and turn white before the grain is fully developed and while the culms and leaves are still green. When affected this way, a large portion of the oats shatters to the ground before and during harvest.

Conclusions.

The average yield of the leading variety in each group at the stations where experiments have been made under irrigation in the northern Great Plains and western basin areas is shown graphically in figure 15.

From the data presented in the preceding pages it appears that in irrigated districts where early frosts may be expected the early yellow varieties are to be recommended. Otherwise, the midseason white varieties, such as Silvermine, Swedish Select, and Early Mountain, are the most desirable for growing under irrigation in the western United States.

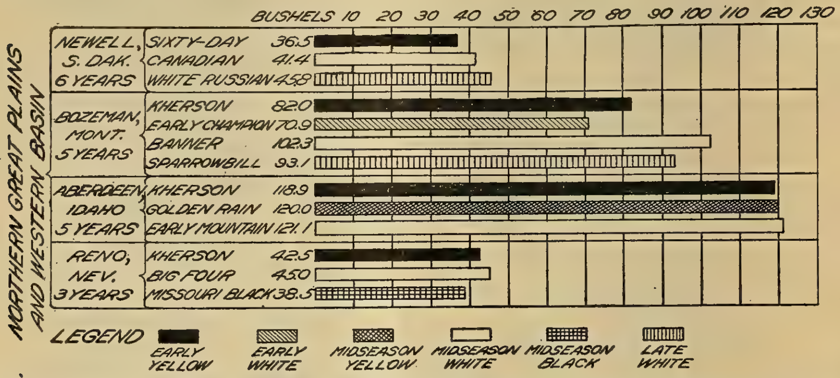

FIG. 15.—Diagram showing the average yields, in bushels per acre, of the highest yielding variety of each of several groups of oats under irrigated conditions at four agricultural experiment stations in the northern Great Plains and western basin areas during the periods of years indicated.

SUMMARY OF DATA.

The name and average yield of the highest yielding variety of early oats grown under humid, subhumid, semiarid, or irrigated conditions, at each of the 48 stations discussed in this bulletin, are shown in Table LV. In parallel columns also are presented the names and average yields of the highest yielding midseason and late varieties, which were grown at the stations in the same period of years except where otherwise indicated. The length of the periods is indicated in the second column.

TABLE LV.—*Average yields per acre of the highest yielding variety of early, midseason, and late oats grown under humid, subhumid, semiarid, or irrigated conditions at 48 experiment stations in the United States.*

Section and station.	Length of record.	Variety.					
		Early.	Yield.	Midseason.	Yield.	Late.	Yield.
North Atlantic (humid):	*Years.*		*Bush.*		*Bush.*		*Bush.*
Orono, Me.	6	Kherson	63.4	Banner	69.7	Senator	56.4
Durham, N. H.	4	do.[1]	35.6	Hamilton	39.3	Long's White Tartar.	42.2
Ithaca, N. Y.	11	Sixty-Day	55.1	Welcome	59.3		
State College, Pa.	4	do.	64.5	Joanette[2]	60.7	Long's White Tartar.	61.9
East North-Central States (humid):							
Wooster, Ohio	9	Sixty-Day	68.2	Siberian	71.3	Long's White Tartar.	65.2
Purdue, Ind.	4	Red Rustproof.[3]	48.7	Great Dakota.	54.0		
Madison, Wis.	3	Sixty-Day	57.6	Wisconsin Wonder.	41.0	White Russian	30.8
De Kalb, Ill.	4	do.	54.2	Schoenen	61.3		
Urbana, Ill.	11	do.	58.1	Siberian	52.5		
Fairfield, Ill.	2	Red Rustproof.[4]	47.1	White Bonanza.	35.0		

[1] Average for two years only.
[2] The average yield for the midseason white variety, Japan, is 60 bushels.
[3] The average yield for the Sixty-Day variety is 47.2 bushels.
[4] The average yield for the Sixty-Day variety is 37.3 bushels.

TABLE LV.—*Average yields per acre of the highest yielding variety of early, midseason, and late oats grown under humid, subhumid, semiarid, or irrigated conditions at 48 experiment stations in the United States*—Continued.

Section and station.	Length of record.	Variety.					
		Early.	Yield.	Midseason.	Yield.	Late.	Yield.
West North-Central States (humid to subhumid):	*Years.*		*Bush.*		*Bush.*		*Bush.*
St. Paul, Minn	3	Sixty-Day	61.1	Myrick Banner	60.5	White Russian	52.4
Crookston, Minn	5	do	53.2	King Oscar	57.4	do	52.8
Grand Rapids, Minn	2	Kherson	84.1	Banner	79.6	do	78.9
Fargo, N. Dak	7	Sixty-Day	63.5	Big Four	59.8	Tartar	60.8
Brookings, S. Dak	14	do	58.1	Swedish Select	47.9	....	......
Ames, Iowa	7	Richland	60.5	Silvermine	57.6	White Russian	46.1
Lincoln, Nebr	14	Burt [1]	58.2	Swedish Select	47.2	....	......
Manhattan, Kans	7	Red Algerian[2]	40.9	Green Russian	35.3	....	......
Lower Mississippi Valley (humid):							
Knoxville, Tenn	5	Kherson [3]	31.2	....	......	....	......
Carthage, Mo	4	Red Rustproof. [4]	24.5	Lincoln	23.5	White Tartar	25.2
Fayetteville, Ark	5	Burt [5]	36.4	....	......	....	......
McPherson, Kans	4	Sixty-Day [6]	37.6	Canadian	22.6	White Tartar	26.8
Denton, Tex	3	Red Rustproof.[7]	41.4	....	......	....	......
Northern Great Plains (semiarid):							
Moccasin, Mont	9	Sixty-Day	58.3	Swedish Select	46.0	White Tartar [8]	24.7
Williston, N. Dak	10	do	50.6	Abundance	71.5	White Russian	61.5
Dickinson, N. Dak	11	Kherson	51.1	Golden Rain	53.5	do	39.2
Mandan, N. Dak	2	Sixty-Day	43.9	do	49.0	do	42.8
Langdon, N. Dak	5	do	41.2	Siberian	54.4	do	57.5
Edgeley, N. Dak	8	do	42.4	do	45.5	do.[9]	37.4
Newell, S. Dak	6	do	40.9	Swedish Select	31.8	do	29.4
Cottonwood, S. Dak	9	do	12.9	do	7.4	....	......
Eureka, S. Dak	9	do	37.1	do	32.3	....	......
Highmore, S. Dak	12	do	37.0	do	30.8	....	......
North Platte, Nebr	6	Kherson	35.4	....	......	....	......
Archer, Wyo	5	Sixty-Day	21.7	Swedish Select	26.4	Black Tartarian.	20.9
Akron, Colo	10	Kherson	38.9	Colorado No. 37	36.6	White Tartar [9]	26.5
Southern Great Plains (semiarid):							
Hays, Kans	4	Burt × Sixty-Day hybrid.	14.8	....	......	....	......
Amarillo, Tex	11	Red Algerian [10]	20.6	....	......	....	......
Western basin and coast areas (semiarid):							
Nephi, Utah	10	Sixty-Day	15.5	Swedish Select	20.6	....	......
Aberdeen, Idaho	3	do	24.5	"Rustless"	24.2	....	......
Burns, Oreg	5	Kherson	30.7	do	34.2	....	......
Moro, Oreg	7	do	48.7	Siberian	49.2	....	......
Pullman, Wash	2	Sixty-Day	77.3	Abundance	81.8	....	......
Puyallup, Wash	3	do	51.7	Swedish Select	63.2	Sparrowbill	59.4
Chico, Calif	4	Red Rustproof. [11]	35.2	Danish Island	32.9	....	......
Northern Great Plains and western basin areas (irrigated):							
Newell, S. Dak	6	Sixty-Day	36.5	Canadian	41.4	White Russian	45.8
Bozeman, Mont	5	Kherson	82.0	Banner	102.3	Sparrowbill	93.1
Aberdeen, Idaho	5	do	118.9	Early Mountain.	121.1	....	......
Gooding, Idaho	5	do. [12]	71.1	Swedish Select	96.6	White Russian	82.4
Reno, Nev	3	do	42.5	Big Four	45.0	Sparrowbill [12]	43.8

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[1] The average yield for the Kherson variety is 55.0 bushels.
[2] The average yield for the Kherson variety is 36.9 bushels.
[3] The average yield for the Burt variety is 31.1 bushels.
[4] The average yield for the Kherson variety is 24.4 bushels.
[5] The average yield for the Kherson variety is 31.3 bushels.
[6] The average yield for the Georgia Rustproof variety is 34.6 bushels.
[7] The average yield for the Sixty-Day variety is 38.4 bushels.
[8] Average for four years only.
[9] Average for six years only.
[10] The average yield for the Sixty-Day variety is 18.9 bushels.
[11] The average yield for the Sixty-Day variety is 32.6 bushels.
[12] Yield for one year only.
[13] Average for two years only.

The summary of average yields presented in Table LV indicates that at more than 50 per cent of the stations under a wide range of climatic conditions, early varieties have outyielded midseason and late varieties. The early varieties, Kherson and Sixty-Day, have given the best results in the warmer humid, subhumid, and semiarid sections. Late varieties have been superior in yield to those of the midseason group at only a few stations.

GENERAL CONCLUSIONS.

In general, the early varieties, Kherson and Sixty-Day, yield well in most of the spring-oat sections of the United States.

In New York and the New England States the best midseason varieties, such as Welcome, Banner, Lincoln, Swedish Select, etc., outyield the Kherson and Sixty-Day and therefore are recommended for growing.

In the higher central and western portions of Pennsylvania, and in western Maryland, northwestern Virginia, and West Virginia, early varieties are superior to midseason or late varieties.

In Ohio there is little choice between early and midseason varieties. Results in Indiana favor the midseason varieties for the central and northern sections of that State.

In central Illinois strains of the Kherson or Sixty-Day type outyield those of the midseason varieties and are preferable for this section. In northern Illinois the midseason varieties are slightly superior.

In southern Indiana and Illinois the early red varieties, such as Red Rustproof and Burt, are the most dependable.

In Michigan and Wisconsin, where conditions are similar to those of New York and New England, midseason varieties outyield the Kherson and Sixty-Day and are recommended.

In most sections of Iowa and in southern Minnesota, southeastern North Dakota, and eastern South Dakota, early oats are well adapted and outyield practically all other varieties.

In northern Minnesota midseason varieties apparently are best adapted.

In the eastern half of Nebraska, Kansas, and Oklahoma, in Missouri and Arkansas, and in western Kentucky and Tennessee, early oats are best adapted. In general the early red varieties, Red Rustproof and Burt, take first rank, with the Kherson and Sixty-Day close competitors in many districts.

In the southern Great Plains under semiarid conditions early varieties are superior. Red Rustproof, Red Algerian, and Burt are the best adapted varieties, with Kherson and Sixty-Day the next best. However, the latter are not as close competitors in this section as in the subhumid portion of the section just to the east, mentioned in the preceding paragraph.

Except at the higher altitudes in the northern Great Plains and at the extreme north, Kherson and Sixty-Day oats usually slightly outyield other varieties. In central and western North Dakota the climatic conditions usually favor the larger midseason varieties.

In the western basin and coast areas, under dry-land conditions, Kherson and Sixty-Day produce nearly as high yields as the best midseason varieties and frequently are preferable, especially in those sections with high altitudes and a short growing season.

Under irrigation in the western United States, midseason white varieties, such as Silvermine, Swedish Select, and Early Mountain, are the most desirable to grow, except that in sections where early rosts may be expected the early varieties, Kherson and Sixty-Day, are recommended. Better results than were expected have been obtained from these early short-strawed varieties when grown under irrigation in comparison with the larger and later varieties.

YIELD OF STRAW, BUSHEL WEIGHT, AND IMPROVEMENT DATA.

Primarily because of the characteristic short, slender culms of the Kherson and Sixty-Day varieties, they do not produce large yields of straw. In sections where straw is relatively valuable for feed, varieties that are low in yield of straw frequently are undesirable. On the average, these early varieties produce from 20 to 30 per cent less straw than the midseason varieties.

In weight per bushel, oats of the Kherson and Sixty-Day type usually fall several pounds below the larger kerneled midseason varieties. This lower weight per measured bushel, however, is more than offset by the lower percentage of hull, which gives them a higher feeding value than other varieties.

One of the objections made most frequently against the early varieties, Kherson and Sixty-Day, is the yellow color of the kernel. In order to eliminate this somewhat undesirable character a number of white-kerneled strains have been developed by selection from the original varieties. Several of these are of considerable promise and are now being grown commercially. Some excellent yellow strains also have been developed. Of these, the most conspicuous is the Richland, a very high-yielding short-strawed variety developed by the Iowa Agricultural Experiment Station, in cooperation with the Office of Cereal Investigations. As yet no variety of any importance has been developed from crosses between the Kherson or Sixty-Day and other varieties.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 824

**Joint Contribution from the Bureau of Chemistry,
CARL L. ALSBERG, Chief, and the Insecticide and
Fungicide Board, J. K. HAYWOOD, Chairman**

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INSECT POWDER.

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PURPOSE OF INVESTIGATION.

As in the case of many other products derived from natural sources, sophistication and adulteration of insect powder have been largely practiced, much to the detriment of the industry. The most serious form of such adulteration has been the addition of the powdered stems of the plant to the powdered flowers, which, in some cases, has been carried to the extent of complete substitution. The work reported in this bulletin was undertaken for the purpose of devising methods for the quantitative determination of such adulteration and for determining reasonable allowances in the amounts of stems and acid-insoluble ash in insect powder.

DEFINITION.

The Insecticide and Fungicide Board of the United States Department of Agriculture (143) [1] recognizes as insect powder an insecticide made from the powdered flower heads of the following species of Chrysanthemum:

1. *Chrysanthemum* (*Pyrethrum*) *cinerariæfolium* (Trev.) Bocc.
2. *Chrysanthemum* (*Pyrethrum*) *roseum* Web. & Mohr.
3. *Chrysanthemum Marshallii* Aschers. (synonym, *Pyrethrum carneum* M. B.).

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[1] References given by number to bibliography on p. 83.

Pyrethrum is a section of the genus Chrysanthemum, which belongs to the Compositæ. The following good description of the two species of Pyrethrum commonly used for preparing insect powder is given in Bailey's Standard Cyclopedia of Horticulture, vol. 2, p. 757 (New York, 1914):

> *Chrysanthemum coccineum*, Willd. (*Pyrethrum roseum*, Bieb., not Web. & Mohr., *P. hybridum*, Hort.). Glaubrous perennial, 1–2 ft. high; stem usually unbranched, rarely branched at the top; leaves thin, dark green, or in dried specimens dark brown; involucral scales with a brown margin; rays white or red in such shades as pink, carmine, rose, lilac, and crimson, and sometimes tipped yellow, but never wholly yellow. Caucasus, Persia.
>
> *Chrysanthemum cinerariæfolium*, Vis. Glaucous perennial, slender, 12–15 in. high; stems unbranched, with a few short, scattered hairs below the flower; leaves long-petioled, silky beneath, with distant segments; involucral scales scarious and whitish at the apex. Dalmatia.

HISTORY.

While all accounts of the early history of insect powder do not agree, the fact that the flowers of certain species of Pyrethrum possessed the property of killing various insects was known to the people of eastern Europe more than a century ago. Thus, according to Siedler (257), insect flowers have been known for more than 100 years in Dalmatia, under the name "Polvere de Pulisi."

The first published reference to the nature of insect powder was made in 1851 by Koch (161), who stated that the flowers of *P. roseum* and *P. carneum* yield the celebrated Persian insect powder. Another early writer on insect powder stated that its nature was kept a secret from western Europe until early in the nineteenth century, when Sumttoff (5), an Armenian merchant, while traveling in the Caucasian region, discovered that insect powder was made from the ground flower heads of *Pyrethrum roseum* and *P. carneum*. In 1818 Sumttoff's son began the manufacture of the powder on a large scale, and about the same time the powder was first exported in large quantities to European countries. It is said, however, that for some time before 1818 Russia had been consuming upward of 200,000 pounds annually. Browne (38), Riley (223), and several later writers give the same account of the discovery of the nature of insect powder, except that the name of the first manufacturer appears as Jumtikoff (7), and the first year of manufacture as 1828. Noodt (205), in 1858, stated that insect powder was known to the inhabitants of Transcaucasia as "guirila." In this connection it may be of interest to know that the name Buhach, applied to insect powder made from flowers grown in California, is derived from the Slavonic word Buha, which signifies a flea. The word Buhach, however, does not appear in the Slavonic language (55).

According to MacOwan (184), the nature of insect powder was made known to Russian military authorities in the Caucasus by some Tcherkess prisoners. The cantonments there swarmed with fleas that could apparently be destroyed only by a powder prepared from *Pyrethrum roseum,* the secret of which was known to the natives.

As to the discovery and history of the *Pyrethrum cinerariæfolium,* from which the Dalmatian insect powder is prepared, still less seems to be known, but it is probable that its history has been very similar to that of the Persian powder. De Visiani (67), in 1854, first mentioned the use of the plant as an insecticide, and Frontali (88), writing in 1858, remarked that the powder prepared from the flowers of *P. cinerariæfolium* had been used for many years in destroying certain insects. Riley (222), in 1881, stated that it was impossible to obtain definite facts on the cultivation of this plant in its native home, as the inhabitants were unwilling to give information concerning a plant the product of which they wished to monopolize. Similarly, great difficulty was experienced in securing even small quantities of the seed of *P. cinerariæfolium* that had not been baked or otherwise treated to prevent germination. Jüttner (150) quotes from an article which traces the discovery of the effect of the flowers of this plant on insects back to 1840, when a German woman, Anna Rosauer, who lived in Ragusa, Dalmatia, picked, for decoration, a bunch of wild flowers, which later, as they became withered, she threw into a corner. After several weeks she noticed that many dead insects lay near the flowers. This led to the discovery that the death of the insects was due to some virtue possessed by the flowers, whereupon she undertook the production of insect powder. After her death a pharmacist of Ragusa continued her work.

According to Linke (173) Persian insect powder was introduced into Europe in 1846, at Vienna, by Zacherl of Tiflis. Willemot (294) states that the first powder of Pyrethrum was introduced into France for the destruction of certain household insects in 1850. The powder came exclusively from provinces of the Caucasus, Persia, and Dalmatia, that from the former being the best, according to the researches of Willemot.

This powder was introduced into the American drug market shortly before 1860 (1). Owing to the fact that no figures on the production in this country are available, and the importation statistics are incomplete, the total amount consumed in the United States can not be accurately stated, but it is certainly in excess of 500,000 pounds annually. According to the committee on the drug market of the American Pharmaceutical Association (159,160,191), the importation of insect flowers and powder at the port of New York for the fiscal years 1885 to 1887, inclusive, was as follows:

TABLE 1.—*Importations of insect flowers and powder at the port of New York, 1885 to 1887.*

Product.	1885	1886	1887
	Pounds.	*Pounds.*	*Pounds.*
Insect flowers	165,505	240,170	262,000
Insect powder	456,609	302,817	335,000
Total	622,114	542,987	597,000

In 1913 not less than 200,000 pounds of insect flowers and stems were imported at the port of New York from Europe, and in addition large quantities were imported at Baltimore and other ports. In 1914, Japan (292) alone sent directly to the United States 379,873 pounds of flowers, and during the fiscal year 1917 (June 30, 1916, to July 1, 1917) the total importation was 1,504,000 pounds. During the recent Great War, the European supply was almost entirely cut off.

CULTIVATION AND HARVESTING OF INSECT FLOWERS.

An account (5), written in 1856, describes the Pyrethrum plants as growing wild in the Caucasian Mountains at an elevation of from 4,500 to 6,800 feet above sea level. These plants blossom in June, and are harvested on a dry day, when an efficient cutter can collect from 30 to 80 pounds a day. The flower heads are usually dried in the sun, although they act more powerfully when the drying is done in the shade.

Several authors (150, 257, 261) have described the cultivation of insect flowers in Dalmatia. According to a communication, under date of November 13, 1915, from Benjamin F. Chase, United States consul at Fiume, the insect powder there is made from the blooms of a wild chrysanthemum (*Pyrethrum cinerariæfolium* Treviranus) which grows in profusion on the east side of the Adriatic Sea, from southern Croatia to Montenegro, on the Dalmatian coast, in Herzegovina and Albania. The annual production for all of this territory is given at from 150 to 200 metric tons. That exported is sent chiefly from Trieste, very little going out from Fiume. With the development of the trade in insect powder has come a cultivation of the wild variety. The plant grows best in rocky and barren hills with little soil, especially in limestone formations. Humid or deep soil is not favorable for its growth. Warm and dry weather is supposed to be best, not only to develop the wild plant but to give it its special insecticidal virtue. The cultivated plant does not produce well the first year, but starts the second year, and, if well cared for, continues to grow from the same root for 20 years. It begins to bloom in May, and is first harvested in early June. One hectare (2.47 acres) of the cultivated variety yields 111,100 plants, producing 2,000 kilograms (4,412 pounds) of dry blooms. The bloom is in best condition for making the powder if cut before opening, or in the "bud." It is cut off just beneath the head. After cutting, the blooms are spread on cloths and dried in the sun. When thoroughly dry they are ground into a fine powder by revolving stones, or by crushers working vertically. The finest quality powder is that obtained from the "buds" or the unopened wild blooms in the region of Krivosije, Dalmatia. The second quality, that from half-opened blooms, comes from Cittavecchia, Dalmatia. The third, from the full blooms, is produced in Ragusa, Dalmatia. The "buds" used in making the first-quality powder are very small, 6 to 8 millimeters in diameter, and look like a large chamomile flower. The cultivated plants bear flower heads with a diameter of from 8 to 10 millimeters, having the rays very close together and covering the crown, being again covered by involucral bracts. Powder of the third quality is prepared from flower heads with a diameter of from 10 to 12 millimeters, almost disclike in form, many of them being without ray florets.

After the nature of insect powder became known, the cultivation of Pyrethrum was taken up in several countries. The growing of *Pyrethrum roseum,* introduced into France about 1856, is described by Willemot (294), and Heckel (123) discusses the cultivation of *Pyrethrum cinerariæfolium* in the botanical garden of Marseilles since 1900. The cost of harvesting the flower heads is the great obstacle to the remunerative growing of the plants in southern France.

In Germany *Pyrethrum roseum* and *carneum* are reported by Schenck (242) as growing well as early as 1859, and their cultivation there was described in detail by Pauckert (209) in 1866. According to Siedler (258), however, experiments made under the direction of the Agricultural High School on the cultivation of different insect-powder-producing species of Chrysanthemum near Berlin in 1886 were without favorable results. In May, 1912, another effort was made to grow the *C. cinerariæfolium* in Germany by planting some seeds from Dalmatia in the garden of the Pharmaceutical Institute of Berlin University. The winter of 1913-14 killed more than one-half of the plants, only a few being left after the winter of 1914-15, but Siedler (258) believes the cultivation of Pyrethrum near Berlin can be made profitable if proper care is taken.

Kalbruner (151), in 1874, stated that in Austria *Pyrethrum roseum* and *carneum* were frequently seen in gardens, and their cultivation in that country was described in 1889 by Labler (166). The cultivation of *C. cinerariæfolium* at Korneuburg near Vienna is taken up in an article by Kuraz (165).

Semenoff (253), in 1878, stated that in the Caucasus the production of Persian insect powder, made from the flowers of *Pyrethrum roseum* and *carneum,* amounted to about 720,000 pounds annually in 1850, but that 20 years later it had decreased to less than one-third of this figure, due to the competition of the Dalmatian powder. The flower heads are collected from wild-growing plants in June and July, and are dried first in the sun and then in the shade.

Simmonds (259), in 1891, reported that the *Pyrethrum Willemotii* (the name given to *P. cinerariæfolium* by Willemot) succeeds well in Algeria. Blin (31) described the cultivation of Pyrethrum at the botanical station of Rouiba, Algeria, in 1903. From 500 to 900 kilograms (1,100 to 1,980 pounds) of dry flowers per hectare (2.47 acres) are obtained, depending upon the soil and the variety of Pyrethrum.

Pyrethrum cinerariæfolium has been grown successfully in Gippsland, the southeastern district of Victoria, Australia, by Paul Kleesattel (17). The seeds were obtained from Zara, Dalmatia, and the plants are of the true Dalmatian type. Some powder prepared from the flowers of these plants is said to have killing properties decidedly above the average. The cultivation of Pyrethrum in Victoria is described in a Melbourne agricultural paper (154). Hellier (126) sowed some seed of the *Pyrethrum Willemotii* in 1872 at Grahams Town, Cape Colony, and also distributed packets of the seed. It grew well, and its insect-destroying power was "something extraordinary." In 1883 Hellier distributed more seed, and in 1890 he reported that there were good specimens of plants at Waterford, in various places in Kaffraria, and near King Williams Town.

MacOwan (184), of the Cape Town Botanic Garden, points out that *Pyrethrum cinerariæfolium* thrives best on an open, dry soil, not too clayey, as both the seed and the plant are easily killed by excessive moisture. The seed, which is sown about half an inch below the surface, germinates in approximately 30 days. As soon as the plants can be handled they are placed 6 inches apart, and three months later, 1 foot apart. The flowers are produced in the second year. In the same article it is stated that the plant appears to stand the winter in sandy loam in the south of England, but has not been observed to flower freely.

In Japan the *Pyrethrum cinerariæfolium* has been grown for some time, and the manufacture of insect powder is a well-established industry. The following information as to its cultivation there was furnished by George N. West, American consul at Kobe, under date of March 22, 1915:

> The species of Pyrethrum cultivated in Japan for the manufacture of insect powder is *Chrysanthemum cinerariæfolium* (white flower, commonly called "Dalmatia"). The *Chrysanthemum roseum* (red flower, commonly called "Persia") is also cultivated to a small extent, not only for the same purpose, but for the beauty of its charming flowers.
>
> None of the species of Pyrethrum are natives of Japan, but have been introduced from foreign countries. As to their introduction, it is hard to say exactly, but the following are some of the most reliable traditions:
>
> 1. During the year 1881, insect powder was first imported by one Tasaburo Shimidzu of Osaka from Bays (?) & Co., of England, through Morff & Co. of Kobe.
>
> 2. Between the years 1884 and 1885 the seeds were imported from Dalmatia and cultivated by Ei-ichiro Murakami of Yasudamura, Arita County, Wakayama Prefecture.
>
> 3. When Georg Hicotrust (?) was a consul for Austria in Japan, he at one time visited Nikko with a view of admiring the natural beauty of the place. It was autumn and the chrysanthemum flowers were blooming profusely along the sides of the road. He thought they looked like the chrysanthemum of his native country which was

used for killing insects, and was surprised to see such a plant growing wild in Japan. He then imported from Austria a small quantity of the seeds which were sent to Wakayama in 1886.

4. While Professor Tamari, present director of Kagoshima Higher Agricultural and Dendrological School, was a student in the United States, he sent some seeds from the California Agricultural School and the California Agricultural Experiment Station to Komaba (near Tokyo) Agricultural College. The seeds were planted there, and were thence distributed to every part of Japan.

The plants are chiefly cultivated in the prefectures of Wakayama, Aichi, Okayama, and Hiroshima, of which the plantations in Wakayama Prefecture are most progressive. Hence the following method of plantation is principally taken from that of this prefecture:

The seed time is twice a year—spring and autumn. When the seeds are sown in the spring the flower does not open in the same year, and therefore in warm districts autumn planting is considered best. Generally in the latter part of September or October a cold bed is prepared, and one-half gill of the best selected seeds, mixed with ashes of wood or fine sand, are sowed on each tsubo (about 4 square yards), covering the whole surface slightly with well-sieved fine earth or sand. Then the surface is pressed with boards and covered with straw or rice hulls, in order to keep the earth from becoming too dry. About 10 days later, when germinated, the straw or hulls are taken off. The seedlings are then thinned out 2 or 3 times, according to thickness, in order to make the intervals between them from 1½ to 2½ inches. Five or six weeks after budding, when the seedlings have grown to a height of over 1 inch, a temporary nursery is prepared, and the strong seedlings are planted at intervals of 4½ to 5½ inches and the weak ones at intervals of 2½ to 4 inches. The following spring they are transplanted to a ridge 2 or 2½ feet high, in a dry rice field, and to a ridge of 2 feet or of ordinary height in a vegetable field. The intervals between the seedlings when transplanted should be 1 foot to 1 foot 3 inches. The fertilizers usually applied are 1,560 pounds of natural forest loam, 40 pounds of superphosphate of lime, 80 pounds of straw ashes, and 2,500 pounds of human excrement and urine for each quarter acre. There are no special methods for plowing, weeding, and irrigation. The plants are propagated not only by seedlings, as just explained, but also by dividing the roots of the plants and transplanting them. After 4 or 5 years the plants become too old, and will not bear many flowers, making it necessary to divide their roots or to sow new seeds.

Sticky or clayey soil should be avoided. Sandy soil is preferable, because the water drains freely. The slope of a hill or reclaimed land may also be used when care is taken and it is fertilized well. No analysis of the soil is obtainable. While in the nursery, a solution of sulphate of ammonia in water is applied, in addition to the fertilizers already mentioned. After transplanting in the spring, the same solution is applied. The superphosphate of lime is also widely used. No manganese salt is applied as fertilizer, but most of the soil in Japan contains a small quantity of manganese.

The flowers are generally harvested during the latter part of May or in June, during which period they are picked over four or five times. When harvested before the flowers are opened fully, the crop is comparatively small, but if harvested after full bloom, the strength of the powder for killing insects is lessened. Care should be taken to select the time of harvesting. The proper time is when the flower petals are fully opened, until their ends are on a level with the top of the calyx and the pollen is falling. Old men and women, carrying hand baskets, can easily pick the flowers by holding them between the middle and fore fingers, and by pressing down at the top of the flower with the thumb. By shaking up and down, the flowers are soon separated from the stem. A woman generally can pick the flowers at the rate of about 40 to 50 pounds during the day.

> In some districts a simpler method of harvesting is adopted. At the time of full bloom, the flowers, together with their leaves and stems, are reaped about twice, with a tool like a short-handled rake with comb-shaped teeth, and dried in the sun. It should be added that powder made from flowers picked by this comb-toothed instrument is either inferior or no good, for the reason that flowers in all stages of blooming are thereby picked, whereas to obtain the full strength flowers must be picked at exactly the right stage of blooming, which can be done only by hand.
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> The flowers picked are spread on straw mats and dried in a sunny place, exposed to the wind. Then they are moved to a drying room, which should have a good draft. Shelves, similar to those used in sericulture, are made by laying down rush screens or old newspapers on the top, where the flowers are arranged thinly and turned over twice or more a day. A few days later, when dried to a certain extent, they may be spread out thicker than at first. The drying is finished in 6 or 7 days. When there is no drying room, they are dried entirely in the sun. By adopting this system, a much greater quantity can be dried in a shorter time, although it is inferior in quality compared with that dried in the shade. Drying in the sun takes only three days in fine weather. If the drying takes too long, the flowers lose their strength Drying has reached the proper stage when the flowers can be roughly powdered by breaking them into small pieces upon rubbing with the thumb and forefinger. Artificial heat is also applied at large factories, the standard of the heat being 150° F.

In addition to the districts named by West, the provinces of Ki-i and Mikawa are mentioned by Fujitani (89) as supplying flowers. Herrera (129) states that the *C. cinerariæfolium* grows well in Mexico.

Efforts to introduce the cultivation of Pyrethrum into this country were made by the United States Department of Agriculture as early as 1859. In that year Bishop (30) reported that 250 plants of *Pyrethrum caucasicum* were in the course of cultivation in the Experimental and Propagating Garden at Washington, D. C. Markoe (188) describes the growing of *Pyrethrum roseum* by Prof. Asa Gray in the Cambridge, Mass., Botanical Garden from seeds distributed by the Government in 1859. The seeds yielded by the American-grown plants were sown but did not germinate. The root stocks of the old plants, however, threw up shoots in the second year. Gray was of the opinion that the cultivation of the plant could be made profitable in this country. In 1860 Abel (1) stated that he was informed by persons receiving some of this seed that the plants were in a flourishing condition. In the eighties the United States Department of Agriculture renewed its efforts to establish the cultivation of insect-powder-producing plants. In Washington, D. C., Riley (222) obtained good results. He distributed seed to correspondents in Alabama, California, Dakota, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Michigan, Mississippi, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, Ontario, Pennsylvania, Vermont, and Virginia, but in all the States, except California, the results were unfavorable, due, apparently, largely to drought and bad seed.

On the other hand, better results were obtained by persons more familiar with growing plants. Thus Peter Henderson wrote Riley (222) regarding *P. roseum:* "I have grown the plant and its varieties for 10 years. It is of the easiest cultivation, either by seeds or divisions. It now ramifies into a great variety of all shades, from white to deep crimson, double and single, perfectly hardy here, and I think likely to be nearly everywhere on this continent." *Pyrethrum roseum* was also grown successfully at Germantown, Pa., and at Archer, Fla. (222), from seed furnished by Riley. In 1884 Riley (225) reported success in growing Pyrethrum in Virginia and in Maryland, and in 1885 (226) in Arkansas and Florida.

King (155), in 1886, reported the results of efforts to grow *P. roseum* in different States. At the Connecticut Experiment Station plants from seed sown in 1884 bloomed in 1885, and then died. At the Michigan station the seasons were too cool and short for the profitable growth of this plant. The New York station reported that "the plants grew well, blossomed, and some of them matured their seed." At the Pennsylvania State College the plants did not bloom. An attempt to grow this plant in Massachusetts is described in the annual report of that station for 1889 (101). The seeds were sown in a hotbed, and subsequently transplanted in the field, but did not mature. In 1891 (102) and again in 1892 (103) it is reported that one row of *P. roseum* was grown in the field. Goff (104) planted seeds of *P. roseum* at the Geneva (N. Y.) Agricultural Experiment Station in the spring of 1887. The plants did not blossom the first season, and were counted as a failure, but in the second spring they started a vigorous growth, and bloomed profusely. The powder prepared from these New York grown flowers was just as active against flies as that from *P. cinerariæfolium* flowers grown in California. Green (105) in 1892 recommended *P. roseum* as an ornamental plant desirable for planting in the region of the Minnesota station. In 1890 Massey (192) announced his intention of trying the cultivation of *P. roseum* and *cinerariæfolium* at the North Carolina Agricultural Experiment Station, but nothing seems to have come of this.

California is the only place in the United States where the cultivation of Pyrethrum has reached commercial proportions. Coquillet (55) states that G. N. Milco introduced the *Pyrethrum cinerariæfolium* into California about 1870, and describes the cultivation of the plant. The amount of the present production of insect powder in California is not known, but in 1888 it was 52 tons.[1]

Klee (158), of the College of Agriculture of the University of California, has carried on extensive experiments on the cultivation of Pyrethrum. At the Southern Coast Range Culture Substation of the University of California, in San Luis Obispo County, Cruickshank (59) in

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[1] Insect Life, v. 1, p. 356, 1889.

1891 reported that Pyrethrum seed sown in the fall grew, and that the plants blossomed a little, although the year was the hardest for 7 years, according to old residents. Shinn (256), of the same station, in 1897, reported on the cultivation of Persian insect powder plants (apparently *P. roseum*) as follows: "Plants endure the winter and bloom freely. They do not grow rapidly, however, and the culture would probably not be profitable here." In the same report (p. 72) Pyrethrum is suggested as worthy of trial as a plant suitable for cultivation on alkali soil, but no experiments seem to have been made to test this idea. Both *Pyrethrum roseum* and *cinerariæfolium* are mentioned as being well established in the garden of the Southern California Culture Substation, in Chino Valley. Schrenk (248), quoting from Semler's "Die Tropische Agrikultur," describes the cultivation of *C. cinerariæfolium* in California by Dalmatians who had settled there.

Within the past few years the *C. cinerariæfolium* has been successfully cultivated at Madison, Wis., and at the Arlington, Va., Experimental Farm of the United States Department of Agriculture, and Halsted (112, 113) has grown hybrids of *C. roseum* and the field daisy (*C. leucanthemum*) in New Jersey. As said before, however, California is the only place in this country where the cultivation of Pyrethrum has continued on a commercial scale.

Summary.—At present insect flowers are cultivated commercially in Dalmatia, Montenegro, Japan, Australia, Algeria, and California. The first three countries produce nearly all the flowers that enter into international trade. In 1907, 2,882,000 pounds, and in 1908, 2,615,000 pounds of insect flowers were exported from Austria (165). Japan, in 1913, exported 349,225 pounds of insect flowers and 211,012 pounds of insect powder, and in 1914, 819,612 pounds of the flowers and 256,567 pounds of the powder (251). As for the wild insect flowers, it appears that Montenegro is the only country where they grow abundantly enough to be of commercial importance, and even there the quantity is small, as, according to Jüttner (150), the whole Montenegrin production of wild flowers amounts at most to 15,000 kilograms (33,000 pounds) each year.

PREPARATION OF INSECT POWDER.

In one of the earliest accounts of insect powder (5) it is stated that the dried insect flowers are rubbed to a coarse powder with the hand, and then ground fine in a small mill. Willemot (294) gives directions for the pulverization of insect flowers in a mortar by simply rubbing them with a pestle. In order to prevent the escape of powder, the mortar should be provided with a leather covering through an opening in which the pestle moves.

Coquillet (55) describes the manufacture of Buhach from the flowers of *Chrysanthemum cinerariæfolium* in California as follows:

> Arriving at the mill the flowers (which have been thoroughly dried) are fed to a set of burr millstones, just as wheat is handled in making flour by the old process. The grist is carried by an elevator to a separator which, by proper sieves, separates the coarser particles of the grist, allowing only the finest, dustlike powder to pass through. This powder is carried by an elevator to an adjoining building, where it is put up in tin cans for the market, while the coarser particles thrown off by the separator are returned to the millstones.
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> The flowers become heated while being reduced to powder, but the latter, in passing through a large series of elevators, loses its heat to a great degree before it is put into the cans for the market.

Slaus-Kantschieder (261), in 1913, described the preparation of insect powder in Dalmatia as follows:

> The flowers are prepared as powder in Dalmatia, as well as in Trieste. The largest Dalmatian mills, located in Sebanico, are driven with electrical power from "Krkafallen." Further, several smaller concerns in Zara, Ragusa, and upon the islands of "Mittel-Dalmatiens" carry on the grinding of the flowers. In Trieste the grinding of the chrysanthemum plants is carried on in about 10 mills, and this is the place where most of the adulteration occurs.

In the United States, in addition to Stockton, Calif., where Buhach is manufactured, insect flowers are ground on a large scale in Baltimore, Peoria, and New York, and to a smaller extent in Philadelphia, St. Louis, and other places. In most cases the older firms still use stone "chaser" mills, while the newer firms employ steel disc mills.

A "chaser" mill consists simply of a pair of millstones joined by a horizontal axis which is connected with a vertical shaft. By means of power the shaft is turned, and the two stones roll around, one after the other, on a heavy block of granite. These millstones, which are also of granite, are about 2½ feet in diameter by 8 inches thick, and weigh several hundred pounds each. Flowers imported into this country are received in bales done up in burlap, containing on an average about 440 pounds net each. The contents of the bales are emptied on the floor, and any large stones, which are sometimes added to give weight, removed. The flowers are then shoveled or dumped into the box which surrounds one of these stone chaser mills, where they are kept in the path of the revolving stones, which are mounted about 2 feet apart, by means of a revolving arm. The flowers are soon reduced to a fine dustlike powder which in some mills is periodically shoveled out, and in others is removed from pockets in the sides of the inclosing box. The powder is so fine that it is carried up by the air currents produced by the revolving stones, and settles into pockets provided for that purpose. The top, as well as the sides of the mill, is boxed in very tightly to keep the powder from flying everywhere. After grinding, the powder is put through a sieve or bolted, and the tailings reground. In some cases a sieve of only 40 meshes to the inch is used, whereas other firms employ 110-mesh bolting cloth.

The steel disc mill, used by some firms in grinding insect flowers, consists of a series of perforated steel discs with lugs on the edge which revolve in a corrugated cylinder at a rate of from 3,000 to 3,500 revolutions per minute. The flower heads are fed into a hopper, either by hand or automatically through a chute, and are thrown with great force against the corrugations on the inside of the cylinder by the revolving discs. The discs do not rub against each other or the cylinder; the flowers are simply cut to pieces by the force of their impact against the sharp corrugations. In a mill of this kind the cylinder opens into a large box or cloth bag of close weave. If a box is used, it must be provided with a number of cloth "chimneys," which may be supported by a wooden framework. The idea of the cloth is to hold in the fine insect powder while allowing the air, which is fanned into a very strong current by the revolving discs, to filter through.

When flowers imported from Japan are ground it is necessary first to run them through a disintegrator, which consists commonly of a mill built like an ordinary large, coarsely-grinding domestic coffee mill. Before being shipped from Japan, insect flowers are wrapped in rattan or similar material, and compressed into as small a bulk as possible in a press. Ordinarily four of these little bales, each of which weighs about 100 pounds, are wrapped together in burlap with metal bands and wooden strips for shipment. The flowers are so compressed in these packages that the use of the disintegrator is necessary. From the disintegrator the flowers travel on a belt to a chute through which they fall to the floor below. An electromagnet is so arranged under the belt that particles of iron, like nails, which may be present in the bale, are removed as the flowers pass down the chute. On the floor below the flowers may be fed directly into the hopper of the disc mill, or they may be run first through a cutter, which further breaks them up and expedites the final pulverization.

In either process the powder becomes quite warm in the grinding, thus losing part of its moisture, but not, apparently, any of its insecticidal constituents. This loss in moisture, together with a slight mechanical loss in the milling process, amounts to 6 or 7 per cent by weight of the flowers ground.

In grinding insect flowers it is not customary to add any material to assist the pulverization. Nor, with the exception of large stones, which may have been added to the bale, and certain bits of iron which are taken out by an electromagnet, is anything removed from the flowers as they are received. Such foreign matter as stems, either adhering or loose, sand, and dirt is allowed to remain.

In Japan the process of manufacture is as follows (292): The flowers are dried in the shade for one day in the summer, after which some 8 pounds are placed in a stone mortar and powdered for about 10 hours. This powder is then put through a sieve, and dried by steam heat at from 80° to 90° for 4 or 5 hours in a drying room. When well dried it is packed in tin containers. In the sieving process from 20 to 25 per cent of the powdered flowers remain in the sieve. This refuse is not used in the best quality insect powder, but some manufacturers repowder it and mix it with the fine good powder. Mixed with the powdered leaves and stems of the Pyrethrum plant, it is used also as a smudge for mosquitoes and flies.

EFFECT OF INSECT POWDER ON INSECTS.[1]

In the account of the discovery of the nature of insect powder by Sumttoff (5) no details are given as to its use. It is simply stated to be one of the most active means of protection against harmful insects, "attracting them by its characteristic odor and then numbing and killing them, but to man and larger animals it is entirely harmless."

Noodt (205), in 1858, wrote:

> The powder has the property of numbing all insects in a short time and subsequently killing them. Strewn in the room and in the bed it is a poison for lice, fleas, bugs, flies, moths, etc. * * * .
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> In the collection of insects it has been used for a long time not only to quickly kill them but also to protect them against other insects, and it can be recommended not only for this use but also in herbariums and other natural history collections, since ants also quickly die from it.

In 1858 Browne (38) recommended the trial of Persian insect powder, or a decoction of it, against the scale of orange trees (*Coccus hesperidum*), but the test does not appear to have been made. This is the first use of insect powder against a definite insect suggested in the United States, and the first time it is spoken of for use on fruit trees. About the same time Willemot (294) records the results of experiments on the destruction of noxious insects in France with Pyrethrum.

Glover (99), in 1864, described the first experiment recorded in this country on the insecticidal efficiency of Persian insect powder:

> This powder had a curious effect on some Croton roaches we were experimenting with; when sprinkled over them or placed in a circle and they made to pass over it, for a few steps they appeared very lively, but soon staggered, and after a few struggles fell over and soon ceased to live.

Saunders (239), in 1879, was one of the first to describe the effect of insect powder upon house flies and green aphis. About the same time Carpenter (44) published the results of his experiments with Pyrethrum on different insects. As a result of these experiments, he states that "all insects having open mouth parts are particularly susceptible to this powerful drug." Howard (138), in 1882, described the effect of Pyrethrum upon the heartbeat of *Plusia brassicæ* (cabbage worm).

A great amount of work has been done since 1879 by the United States Department of Agriculture and the various agricultural experiment stations in testing the efficacy of insect powder in destroying or repelling harmful insects, but a review of such work would be foreign to the purpose of this bulletin. Those interested may consult the following list of references to recorded tests given in the bibliography (p. 83): 2, 3, 9, 11, 26, 27, 28, 35, 36, 38, 44, 46, 49, 51, 52, 53, 54, 55, 56, 61, 65, 66, 71, 72, 75, 87, 94, 96, 97, 98, 99, 100, 104, 120, 125, 128, 129, 138, 141, 148, 149, 151, 157, 165, 167, 171, 176, 178, 192, 193, 195, 200, 201, 203, 207, 208, 211, 217, 218, 221, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 241, 258, 262, 263, 264, 270, 271, 272, 290, 291, 294. For a list of other articles on the use of insect powder against different insects, see "Bibliography of the More Important Contributions to American Economic Entomology," published by the United States Department of Agriculture, Bureau of Entomology, Washington, 1890-1905. The "Index to the Literature of American Economic Entomology," published by the American Association of Economic Entomologists, 1917, gives references from 1905 to 1914.

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[1] The statements given under this heading are merely quotations from the literature and are included for their historic interest. They are not to be taken as representing the present opinion of the Department of Agriculture concerning the efficacy of this product.

On looking over the literature it will be noted that the results of the various investigators of the powder differ in many respects. Some claim that the powder must be taken internally to be effective, while others state that it kills by external contact. In many cases the reported failures of the powder were no doubt due to the fact that a powder adulterated with powdered stems was used in the tests, the experimenter accepting, as pure, commercial powders the composition of which he had no way of knowing.

At present insect powder is used largely against bedbugs, cockroaches, ants, flies, mosquitoes, and certain other household insects, as well as plant lice, and fleas on pet animals.

Although insect powder is an efficient insecticide against many insects, it appears that the plant from which it is made is not free from insect enemies. In 1884, W. Allan, of Baltimore County, Md., sent Riley (225, p. 416) specimens of *Macrodactylus subspinosus*, found on Pyrethrum plants in large numbers and apparently eating both leaves and flowers, and *Chauliognathus marginatus*, not so numerous and apparently attracted chiefly by the flowers. Riley states that a number of insects are known to feed on Pyrethrum while it is growing. In 1890 Riley (229) again called attention to the fact that the *Macrodactylus subspinosus*, or rose chafer, devours the blossoms of the *Pyrethrum cinerariæfolium*. This fact, however, does not seem so surprising, as, according to Smith (263,264), insect powder is entirely ineffective against the rose chafer.

EFFECT OF INSECT POWDER ON ANIMALS.

While it is generally considered that insect powder is harmless to the higher animals, a number of cases where it has produced symptoms of a more or less serious nature are recorded.

As early as 1858 Boucard (34) described the case of a woman, who had strewn much insect powder upon her bed, being taken with a headache, roaring in the ears, bloating of the face, pain in the stomach, nausea, sweating, and symptoms of syncope. About the same time Von Wiggers (8) abstracted a report by an anonymous writer of a case in which a man and his son who had scattered Persian insect powder in their beds passed a restless night, during which they suffered from painful dreams, and the next day had bad headaches. In 1884 Riley (225), in speaking of the supposition that Pyrethrum has no effect on the higher animals, stated his own experience in which the fumes of the powder in a closed room intensified sleep and produced stupor. Coquillet (55) states that insect powder has no injurious effect upon human beings.

It appears also that there is a difference of opinion with respect to the action of Pyrethrum when taken into the stomach. Milco wrote Coquillet that a teaspoonful of the alcoholic extract of Buhach was administered to a certain person afflicted with tapeworm. The dose was repeated every hour for 10 consecutive hours, as a result of which the tapeworm was removed without injuring the patient in the least. On the other hand, Noodt (205) states that taken internally insect powder was inactive against the tapeworm, but against Ascarides it was effective when a concentrated infusion was used as a clyster. Likewise an injection of this powder against maggots in the outer ear passages had a remarkable effect. Tests showing anthelminthic properties in the flowers of *P. roseum* and *carneum* are recorded by Schipulinsky (244) in 1854, and Frontali (88) records the same for the flowers of *C. cinerariæfolium* in 1858.

According to the Chemist and Druggist (21), an American doctor in 1898, through an accident to a child, found that insect powder has anthelminthic properties. In 1888 Holmes, in discussing a paper by Kirkby (156), reported a case from Hull, England, where a man had died from the effects of insect powder, but whether the death was due to the powder itself or to some adulterant was not determined. Schlagdenhauffen and Reeb (246) record the poisoning of 7 persons in 1889 from 1 pound of insect powder which had been strewn in their beds. Bosredon (33), in 1897, recorded an instance of poisoning with insect powder. An infant, aged 11 months, playing with a cardboard box of the powder, broke the lid, which scattered the powder into the eyes, mouth, and nostrils. When medical aid arrived convulsions and vomiting had set in, the heartbeats were feeble, and the respiration slightly quickened. After carefully removing the adherent powder, an emetic of ipecacuanha produced free vomiting, and, except for slight inflammation of the conjunctiva, the patient quickly recovered. Additional cases of poisoning with insect powder are described by Mendelsohn (194), Ferrand (81), and the Chemist and Druggist (16). In the only fatal case the patient, a little girl, 2 years old, had eaten about half an ounce of the powder.

Certain species of Chrysanthemum are used as medicine in various countries. Eastes (74) states that *C. parthenium* is official in the French Codex, and is reputed to have tonic, stimulative, sudorific, diuretic, antipyretic, emenagogic, and anthelminthic properties. According to Henry (127) many chrysanthemums are used as medicine in China. A case of poisoning with *C. indicum* is described by Hoffmann (135). In the report of Remington (215) on the Centennial Exhibition, the flowers of *Chrysanthemum album* and *flavum* are said to be used in China for flatulency, and *Pyrethrum parthenium* is included in a list of drugs from Chile, although its use is not given. Stearns (266) lists *Chrysanthemum leucanthemum* and *Pyrethrum parthenium* as plants whose flowers were used in medicine by the natives of Michigan in the fifties. Sato (236) speaks of insect powder (made from flowers of *C. cinerariæfolium*) being used in medicine, as well as for insecticidal purposes.

In regard to the effect of insect powder upon mammals other than man, Riley (225) cites a case in which the powder was copiously rubbed on a dog, as a result of which the animal became sick, being affected in the locomotive organs very much as insects are. Carruthers (45) states that *Pyrethrum inodorum* is credited with producing lasting injury to the digestive organs of stock by damaging the lining of the stomach, and causing death when eaten in large quantities. Coquillet (55) reports that horses fed upon the dried stems of the *Pyrethrum cinerariæfolium* plant appeared to relish it very much, and were not injured in the least by it. In 1880 Sayre (240) performed experiments showing the toxic action of insect powder made from the flowers of *Pyrethrum roseum* upon tadpoles. Fujitani (89) and Reeb (214) record experiments made upon frogs, fish, dogs, and other animals with what they regarded as the active principle of Pyrethrum flowers. These tests, however, were made with extracts of the flowers and after certain chemical treatment, so that the results obtained are not strictly comparable with the action of insect powder itself.

ADULTERATION OF INSECT POWDER.

Insect powder appears to have been extensively adulterated from the time it first entered into commerce. The fact that its nature remained unknown until 1818, when Sumttoff discovered that it was made by pulverizing the flower heads of certain species of Pyrethrum, and the fact that the active insecticidal constituent has not been definitely determined up to the present, rendered the fixing of an exact standard difficult. Sophistication has been correspondingly easy.

In 1851 Koch (161) noted that in Transcaucasia the Persian insect powder is adulterated with flowers of *Pyrethrum corymbosum* and other similar plants, and in Germany with chamomile. De Visiani (67), in 1854, mentioned the flowers of the common chamomile, *Anthemis cotula*, *Anthemis arvensis*, and *Spartium junceum*, as adulterants. In one of the earliest accounts of the nature of insect powder, that of Noodt (205), written in 1858, it is stated that the producers, in order to satisfy the great demand for the product, grind not only flowers, but also stems and leaves, thereby detracting from the quality. He states that merchants in Germany also were in the habit of mixing fresh consignments with old, long-kept goods which had deteriorated with age. Schenck (242), in 1859, noted the use of German chamomile as an adulterant.

In 1861 Willemot (294) said that the numerous adulterations which insect powder imported into France between 1850 and 1860 had undergone prevented the public from appreciating its efficacy. He mentioned the following as having been found in various powders: Sumac powder, jalap, cockle of Levant, nux vomica, and arsenic. Abel (1) reports that Persian insect powder was adulterated with fleabane and chamomile flowers at the time of its introduction to the American market, shortly before 1860.

Schlotshauber (247), in 1862, found the Persian powder to contain a variety of *Pyrethrum corymbosum* W., *Pyrethrum tenuifolium* Tenore, and a variety of *Anthemis arvensis* Linn. Landerer (167, 168), in 1875–1877, mentioned the following as adulterants: *Anthemis cotula*, *Chrysanthemum segetum*, *Matricaria parthenium*. In 1875 Miller (196) reported that old-stock German or Roman chamomile flowers were ground up with insect powder.

Lead chromate as an adulterant appears to be first mentioned by Grote (108) in 1880. In the same year, Kral (164) reported finding a number of samples colored with curcuma, but none with lead chromate. Howie (139), in 1883, gave a method for the detection of fustic, which he found as an added coloring matter in insect powder. At a meeting of the Liverpool Chemists' Association in March, 1883, Conroy (50) exhibited samples of imported insect powder which were heavily adulterated with fustic. Schwarz (250), in 1888, reported finding a sample colored with an alcoholic solution of curcuma.

Mason, in discussing a paper by Kirkby (156), reports having had a sample of "Dalmatian insect powder" which contained 60 per cent of sumac and 30 per cent of chamomile. Howie, in the same article, mentions that he found a large proportion of potato starch in a cheap powder.

Unger (282, 283, 284), 1888–1890, found the following adulterants in insect powder: Pyrethrum stems, barium chromate, lead chromate, curcuma, and *Chrysanthemum leucanthemum* (Hungarian daisy). Schrenk (249), in 1889, also mentioned the Hungarian daisy, sometimes known as the Russian daisy, as an adulterant. He stated that starch is a very common adulterant. Beringer (29), in 1889, reported that insect powder brought into America was extensively adulterated with the Hungarian daisy, and that the ground stems and leaves of the Pyrethrum plant were also used as adulterants. Hart (119), in 1888, reported yellow ocher and wheat starch as adulterants.

In the same year, Marpmann (190) reported the use of the powdered root of *Veratrum album* as an adulterant of insect powder.

Thompson (273), in 1891, examined 7 samples of insect powder put out by American manufacturers, 2 of which were adulterated with lead chromate. Verneau (285), in 1892, listed the adulterants of insect powder as follows: *Croton flavens, Anthemis cotula, Chrysanthemum segetum, Matricaria parthenium, Tanacetum vulgare, Chamomile romaine, Chrysanthemum leucanthemum,* and wheat starch. Jelliffe (148), in 1895, spoke of the extensive adulteration by means of the stems of the Pyrethrum plant, and proposed methods for the detection of stem tissue in a powder. Caesar and Loretz (42) report that in their examination of commercial insect powders they have noted the following adulterants: Quillaja, euphorbium, powdered whole chrysanthemum plant, quassia, powdered aloes, senna leaves, Hungarian daisy, saffron, and lead chromate.

In 1899, Huber (142) found 2 out of 5 brands of insect powder examined to be adulterated with ground oxeye daisy flowers. Tschirch and Oesterle (281) give *C. coronarium* and *Inula pulicaria* in addition to many of the flowers previously mentioned as being used as adulterants. Collin (47) identified a sample of "false" insect flowers as *Chrysanthemum pallens*.

Hockauf (134), in 1903, listed the following adulterants of insect powder: Flowers of different species of Chrysanthemum (*Chrysanthemum leucanthemum, C. corymbosum, C. inodorum, C. indicum*); different species of Anthemis (*Anthemis arvensis, A. tinctoria, A. cotula*); and *Helichrysum italicum*. In the same year Jean (147) stated that he had found potassium chromate and sawdust in commercial insect powder, and Haywood (122) gave the results of the examination of 105 samples, 19 of which were found to be colored with lead chromate in amounts ranging from 0.12 to 1.47 per cent.

Hanausek and Winton (118) give the following as adulterants: Heads of *Chrysanthemum leucanthemum, Helichrysum arenarium* DC. (*Flores Stœchadis citrinæ*, yellow cat's paw, hour-glass weed, yellow-moth weed), and the stems and leaves of *Chrysanthemum cinerariæfolium*. H. Wippell Gadd and Sydney C. Gadd (90), in

1905, mentioned turmeric and chrome alum as adulterants, and gave methods for their detection. Three years later Grieb (107) found a sample adulterated with borax.

In 1912 Linke (173) mentioned the following: Pyrethrum stems, flowers of other species of Chrysanthemum, calendula flowers, curcuma, lead chromate, barium chromate, euphorbium, and quillaja bark. He stated that the last two are added to increase the aroma of a powder. In the same year Sattler (238) reported lead chromate as an adulterant.

Jüttner (150), who visited the insect-powder-producing regions of Dalmatia and Montenegro in 1912, calls attention to the extensive grinding of Pyrethrum stems in those countries. In order to make this stem powder correspond in color to the genuine insect powder, lead chromate is used, and, to increase the odor, from 1 to 2 per cent of pepper powder is sometimes added.

Siedler (150) mentions another substance used to color insect powder, namely, yellow wood, or the heartwood of *Chlorophora tinctoria*. He mentions also *Pyrethrum indicum*, *Bellis perennis*, *Tanacetum vulgare*, chamomile, quassia powder, pepper, powdered aloes, euphorbium powder, senna leaves, and flowers of "Margherita silvatica" as adulterants. The last name is unknown in botanical nomenclature, and Siedler considers it to be a fantastic designation for an unknown adulterant. Marguerite, however, is a common name for *C. frutescens*, which may be the flower meant. In a later article Siedler (257) stated that, compared to adulteration with stem powder, adulteration with foreign flowers is insignificant.

Slaus-Kantschieder (261), in 1913, stated that in Dalmatia the most usual form of adulteration of insect powder consists in grinding with the flowers a part of the flower stems called "stecco." Lead chromate, barium chromate, powdered bricks, starch, curcuma, and powdered almond shells are also mentioned by him as adulterants. Benjamin F. Chase, United States consul at Fiume, under date of December 15, 1915, reported that in Dalmatia it is customary to add per cent of borax to the inferior grades of insect powder.

In addition to the powdered stems of the Pyrethrum plant, which have been the most extensive means of adulteration, other adulterants etected in the Insecticide and Fungicide Laboratory during the past years have been lead chromate, potassium chromate, barium chromate, curcuma, sand, leaves of the Pyrethrum plant, and oxeye aisy flowers (*Chrysanthemum leucanthemum*).

Roark and Keenan[1] have made a special study of the adulteration f insect powder with powdered oxeye daisy flowers, and have de-cribed means for its detection.

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[1] U.S. Dept. Agr. Bull. 795, issued July 28, 1919.

SUMMARY.

Substances that have been used to color or adulterate insec
powder may be classified as follows:

To give color:
  Lead chromate.
  Barium chromate.
  Potassium chromate.
  Curcuma (turmeric, the root of *Curcuma longa* L.).
  Fustic (wood of *Chlorophora tinctoria* L.).
  Saffron (dried stigmas and tops of the styles of *Crocus sativus* L.).
  Yellow ocher.

Other species of flowers:
  Pyrethrum corymbosum W.
  Pyrethrum tenuifolium Tenore.
  Pyrethrum indicum.
  Chrysanthemum segetum.
  Hungarian daisy, Russian daisy, oxeye daisy (*Chrysanthemum leucanthemum*).
  Garden daisy (flowers of *Bellis perennis* L.).
  German chamomile (dried flower heads of *Matricaria chamomilla* L.).
  Roman chamomile (dried flower heads of *Anthemis nobilis* L.).
  Corn chamomile (*Anthemis arvensis* L.).
  Mayweed (*Anthemis cotula* L.).
  Feverfew (*Matricaria parthenium* L. Synonyms: *Chrysanthemum parthenium* (L. Pers.; *Pyrethrum parthenium* Sm.).
  Croton flavens.
  Tansy (leaves and tops of *Tanacetum vulgare* L.).
  Calendula, marigold (dried ligulate florets of *Calendula officinalis* L.).
  Yellow cat's paw, hourglass weed, yellow-moth weed (*Helichrysum arenariu* DC. *Flores Stæchadis citrinæ*).
  "Margherita silvatica" (*Chrysanthemum frutescens*).
  Chrysanthemum coronarium.
  Inula pulicaria.
  Chrysanthemum pallens ("false insect flowers").
  Chrysanthemum inodorum.
  Anthemis tinctoria.
  Helichrysum italicum.
  Anthemis cotula.
  Spartium junceum.

Miscellaneous adulterants:
  Almond shells.
  Aloes (inspissated juice of leaves of various species of aloes).
  Arsenic.
  Borax.
  Brick dust.
  Chrome alum.
  "Cockle of Levant."
  Euphorbium (gum-resin from *Euphorbium resinifera* Berg.).
  Fleabane, horseweed (leaves and tops of *Erigeron canadensis* L.).
  Hellebore (powdered root of *Veratrum album*).
  Jalap (dried tuberous root of *Exogonium purga* (Wend.) Benth.).
  Nux vomica (dried, ripe seed of *Strychnos nux vomica* L.).

Miscellaneous adulterants—Continued.

- Pepper.
- Quassia (wood of *Picrasma excelsa* (Swartz) Planchon; and of *Quassia amara* L.).
- Quillaja, soap-bark (dried bark of *Quillaja saponaria* Molina, deprived of its periderm).
- Sawdust.
- Senna leaves (dried leaves of *Cassia acutifolia* Delile; or of *Cassia angustifolia* Vahl.).
- Starch, potato.
- Starch, wheat.
- Starch, variety not specified.
- Stems and leaves of insect powder plant.
- Sumach (dried fruit of *Rhus glabra* L.).

HOW TO DETECT ADULTERATION.

The methods which have been used in determining the genuineness of insect powders may be classified in 3 groups:

1. *Physiological.*—The powder to be tested is tried out directly on one or more species of insects, and the time necessary to produce death compared with the time in which the same quantity of a known genuine insect powder will kill the insect.

2. *Microscopical.*—Adulterants are detected by observation through the microscope, either with or without staining or other preliminary chemical treatment.

3. *Chemical.*—The ash, ether extract, and other chemical determinations are made and the results compared with the average values for genuine powders.

PHYSIOLOGICAL METHODS.

Kalbruner (151), in 1874, was the first to record the physiological testing of insect powder. He states that 4 grains of a good insect powder sprinkled on a fly in a vial should produce stupor in 1 minute and death in 2 or 3 minutes. Testing a number of commercial powders in this manner, he found that from 15 to 30 minutes were required to kill flies. Flowers representing a number of species of plants, as well as the powdered stems and leaves of *Pyrethrum roseum* and *cinerariæfolium*, were tested in this way, and found to be quite worthless, as compared with genuine insect powder.

In 1876, De Bellesme (63), in his research on the active principle of Pyrethrum, in order to show that its action was not the mechanical one of closing the pores of an insect, sprinkled flies with insect powder and also with powdered leaves, wood, and various other inert substances. Those sprinkled with the Pyrethrum powder were almost dead after 1 hour, while those left for 10 hours in the inert powders were uninjured.

In 1880, Sayre (240) tested the effect of the flowers of *Pyrethrum roseum* on flies and tadpoles. Unger (282), in 1888, while examining insect powders, made use of Kalbruner's "fly test." He, however, used a weighed amount of powder placed on a sheet of white paper, over which the insect was imprisoned with a glass. Tested against *Blatta orientalis* (Oriental cockroach or black beetle) and *Acarus farinæ* in this manner, the powder from both the *P. cinerariæfolium* and the *P. roseum* killed the insects in about 45 minutes. About the same time, Goff (104), in America, made tests with *P. cinerariæfolium* grown in California and a powder prepared from the flowers of *Pyrethrum roseum,* grown in New York from seed received from the United States Department of Agriculture, to determine the relative time required to paralyze flies. These tests indicated that the powder made from *P. roseum* was slightly more effective.

Hirschsohn (133), in 1890, while investigating the active constituent of insect powder, tested the activity of the powder by trying it on roaches. Two of the samples under investigation paralyzed roaches in 3 minutes. From his tests on *Blatta orientalis,* Thoms (275) concluded that the physiological test was surer than either the microscopical or chemical test in arriving at an estimation of the worth of a powder.

In 1895, Jelliffe (148) tested the action of insect powder on the common house fly (*Musca domestica*), the Croton bug or cockroach (*Blatta germanica*), the bedbug (*Cimex lectutarius*), and some black beetles (species undetermined).

Dowzard (71), in 1899, conducted some tests on cockroaches. Slaus-Kantschieder (261), in 1913, stated that although the microscopical and chemical methods of examination furnish a basis for the grading of insect powder, for the determination of the true value the physiological test must be made. He conducts the test as follows: A 25 cc. flask is taken, about 1 gram of insect powder added, the flask then closed and shaken well, after which the flies are introduced. If the powder is of good quality the flies will come to rest within one half minute and die within 5 minutes. If the flies survive this period the insect powder is to be considered as of low value and old.

Kuraz (165) has recently tested a number of commercial samples of insect powder, as well as closed, half-closed, and open flowers, and Pyrethrum stems grown at Korneuburg, near Vienna, according to the method of Slaus-Kantschieder. The ordinary house fly (*Musca domestica*) was used in these tests, and the time noted in which the insect fell over on its back. The results are summarized in Table 2.

TABLE 2.—*Physiological examination of insect powder.*[1]

Product.	Time required.					
	Minimum.		Maximum.		Average.	
	Min.	*Sec.*	*Min.*	*Sec.*	*Min.*	*Sec.*
Commercial powder ground from wild flowers	0	40	1	45	1	09
Commercial powder ground from Montenegrin closed flowers	1	04	2	45	1	43
Commercial powder ground from Dalmatian half-closed flowers	1	00	2	22	1	34
Commercial powder ground from Dalmatian open flowers	2	03	4	27	3	00
Commercial powder	5	50	15	14	10	05
Commercial powder ground from open Dalmatian flowers	2	20	4	50	3	28
Commercial powder ground from closed Dalmatian flowers	0	45	1	55	1	18
Commercial powder ground from closed Montenegrin flowers	0	40	1	34	1	04
Commercial powder	3	52	10	00	6	02
Powdered closed flowers grown at Korneuburg, 1913	1	20	2	33	1	53
Powdered half-open flowers grown at Korneuburg, 1913	0	54	1	48	1	18
Powdered closed flowers grown at Korneuburg, 1914	0	45	1	43	1	10
Powdered half-open flowers grown at Korneuburg, 1914	0	40	1	45	1	15
Powdered open flowers grown at Korneuburg, 1914	0	40	1	28	1	02
Powdered stems grown at Korneuburg, 1914	3	05	8	49	5	16

[1] 50 tests were made on each sample.

In testing the action of insect powder against various insects Smith (263) and many other entomologists used different brands of commercial insect powders. Their results were comparative, as they were without samples of known purity, and their experiments are without value in showing the presence of adulterants.

MICROSCOPICAL METHODS.

There has been much divergence of opinion as to the value of a microscopical examination of an insect powder in determining its genuineness. For instance, Jelliffe (148) concludes that "the microscope is the only possible means for detecting the presence of powdered stems in insect powder." On the other hand, Beringer (29), after examining genuine insect powder and the powder made from the flowers of the Hungarian daisy, says, "Microscopically no difference could be detected between the two powders." Howie (139) states that he finds chemical methods more exact and trustworthy than microscopical ones for detecting added fustic, chrome, and turmeric. Again, in discussing Kirkby's (156) paper, he says that he has little faith in microscopical observation for ascertaining the value of an insect powder, the physiological test with the black beetle being the best.

For recognizing the presence of certain adulterants, as for instance starch or starch-bearing materials, the microscopical examination is of great value, but in the powdered state flowers of certain of the Compositæ closely allied to Pyrethrum are so similar to insect flowers as to render their detection difficult. Again, although an adulterant can usually be detected qualitatively by the microscope, no exact quantitative method has as yet been devised for its determination.

Trottner (278) has worked out a method in which the value of an insect powder is determined by estimating the number of pollen grains in 1 milligram of the sample. His results, however, vary greatly, as shown in Table 3, which summarizes all of his reported determinations.

TABLE 3.—*Number of pollen grains per milligram of insect powder.*

Product.	Pollen grains in 1 milligram.
Closed flowers of *C. cinerariæfolium* pulverized in a mortar	2,881
Do	2,159
Open flowers of *C. cinerariæfolium* pulverized in a mortar	545
Do	210
Do	151
Commercial powder ground from closed flowers (Riedel)	3,066
Commercial powder ground from open flowers (Riedel)	158
Commercial powder ground from closed flowers (Cæsar and Loretz)	2,255
Commercial powder ground from half-closed flowers (Cæsar and Loretz)	920
Commercial powder ground from open flowers (Cæsar and Loretz)	785
Commercial powder ground from closed flowers (Schuchardt)	4,402
Commercial powder ground from half-closed flowers (Schuchardt)	5,544
Commercial powder ground from open flowers (Schuchardt)	1,319
Commercial powder (Apothecary A)	2,071
Commercial powder ground from wild closed flowers (Apothecary B)	1,235
Commercial powder (Apothecary C)	1,176
Commercial powder ground from cultivated closed flowers (Apothecary D)	575
Commercial powder (Apothecary E)	550
Pulverized closed flowers of *P. roseum*	4,721
Pulverized open flowers of *P. roseum*	2,264
Flores Pyrethri rosei, pulvis No. 0 (Gehe and Co.)	5,741
Flores Pyrethri rosei, pulvis No. 1 (Gehe and Co.)	3,482

MORPHOLOGY OF WHOLE INSECT FLOWERS.

The flowers usually employed in the production of insect powder or Pyrethrum powder are derived from either the Dalmatian or the Persian insect flowers, botanically known as *Chrysanthemum cinerariæfolium* (Trev.) Bocc. and *Chrysanthemum roseum* Web. & Mohr., respectively. The Dalmatian flowers compose the greater part of the commercial insect powders, the Persian flowers being rarely seen in commerce at the present time. Of recent years, Japanese insect flowers have been coming into the market. According to one authority (24) the form known as *Chrysanthemum indicum,* with a yellow ray flower, is widely spread through China and Japan, while in the mountains of Hupeh occurs a white or pink rayed form, which has been named *Chrysanthemum morifolium.* Dr. Henry, who has collected specimens which are in the Kew herbarium, considered these two wild plants the probable progenitors of the cultivated strains. As far as histological characters are concerned, the Japanese flowers can not be distinguished from *Chrysanthemum cinerariæfolium.*

A review of the literature has shown that some little work has been done on the morphology of the whole insect flowers. The descriptions to follow are condensed reviews of the most important articles. They are somewhat abbreviated for the reason that the literature already contains numerous descriptions of the flowers, also because it is considered more expedient at this time to place the greatest emphasis upon those diagnostic characters whereby commercial powder may be accurately analyzed microscopically.

Siedler's (150) (258) morphological description of the Dalmatian flowers, which is quite in detail, may be summarized as follows: The Dalmatian flower stem is 8-sided and very hairy; receptacle slightly arched; involucre consisting of 3 rows of scales, the inner scales lanceolate and about 4 mm. long, the scales of the middle row about 6 mm. long. All of the scales have a flat inner surface, the outer surface being more or less keeled, possessing a scarious margin and covered with hairs. The whitish ray flowers measure about 15 mm. in length and 4 mm. in width, 3-toothed at the tip, the middle tooth being somewhat smaller than the other two. The disc flowers are tube-shaped and 5-toothed, possessing the typical Compositæ oil glands and containing more or less of the yellow, 3-pored, spiny pollen grains. The fruits of the ray flowers exhibit a different structure from those of the disc flowers, being somewhat flattened on the side lying next to the outer bracts, and possessing 2 furrows, while the inner side has 3. The fruits of the disc florets consist of 4, sometimes 6, nerves. A small crown is present on all the fruits.

Collin (47) designated 3 distinct commercial varieties of Dalmatian insect flowers:

1. *Closed flowers.*—Flower heads, varying from 3 to 7 mm. in diameter, generally furnished with a very short striated peduncle. Bracts, greenish-yellow, closely appressed. Corollas of ligulate florets almost always entire; grayish-white in color, and wrinkled and shriveled over the tubular florets, so as to conceal them almost completely. Very few expanded flowers present; very few fragments of corollas, ovaries, or bracts mixed with flower heads.

2. *Half-closed flowers.*—Peduncle longer, even 4 or 5 cm. long. Flower heads full, bracts with a yellowish-gray color. Ligulate florets can usually be distinguished; tubular florets still retain their corollas more or less intact.

3. *Open flowers.*—Recognized by the size of the flower heads, many of which attain a diameter of from 9 to 11 mm. Usually completely expanded when gathered and hence few of them intact; some ligulate florets destitute of corollas and in many others the corollas of the tubular florets have been separated from the ovaries which remain attached to the receptacle. This variety contains abundant débris of the corollas and ovaries, and therefore is not as choice commercially as classes 1 and 2. He described the various parts of the Dalmatian flower head as follows: Bracts, outermost thicker and shorter than the others; more strongly curved and more pointed at the apex; those from the middle row lanceolate, slightly curved; the inner scales are as long as the middle ones but thinner

and spatulate in shape. All scales thickened in the center, gradually becoming thinner toward the margin, which is scarious and transparent. Ligulate florets with 3 teeth at the apex, central tooth smaller than the other two. Calyx with fringed or slashed margin. Ovary possesses 5 projecting ridges. Tubular floret corolla rather deeply 5-toothed. Peduncle channeled and hairy.

The Persian (186) or Caucasian insect flowers (*Chrysanthemum roseum*) differ somewhat from the Dalmatian flowers, and will be but briefly described. The flower heads somewhat resemble those of the Dalmatian variety, but are a little smaller. Ray florets, a reddish-purple tinge; involucral scales, dark and with reddish-brown edge. Fruits usually 10-ribbed. Involucre not as hairy as that of the Dalmatian flower.

SUMMARY.

Dalmatian flowers.—Involucre: Imbricate and campanulate; scales matted with hairs; individual bracts slightly thickened or keeled, the inner bracts becoming thinner and more chaffy or scarious at the margin.

Ligulate florets: Yellowish-white or of a light straw color; pistillate; apex 3-toothed, the middle tooth usually being shorter than the other two.

Disc florets: Perfect, deeply 5-toothed, and yellowish in color.

Achenes of ligulate florets: Distinctly 5-ribbed; rather more flattened and curved than achenes of disc florets and somewhat larger; possess small-toothed crown.

Achenes of disc florets: Distinctly 5-ribbed; not as curved or flattened as those of the ligulate florets; somewhat smaller; possess small-toothed crown.

Persian flowers.—Involucre: Imbricate and campanulate; scales almost glabrous; hairs numerous in depression at juncture of peduncle and receptacle; scales dark and bordered by a distinctly reddish-brown edge; inner scales more scarious than outer ones; appear to be more densely fibrous than those of the Dalmatian flower.

Ligulate florets: Tinged a rather purplish-red; pistillate; apex 3-toothed, middle tooth often somewhat longer than the other two.

Disc florets: Perfect, deeply 5-toothed.

Achenes of ligulate florets: Usually 10-ribbed; more flattened and curved than achenes of disc florets and somewhat larger.

Achenes of disc florets: Usually 10-ribbed; not as curved or flattened as those of the ligulate florets; somewhat smaller.

MICROSCOPICAL CHARACTERISTICS OF INSECT POWDER.

Before taking up the general plan followed by the authors in the microscopical examination of a commercial powder, the most important work done by other investigators will be reviewed briefly.

Collin (47) has condensed the descriptions of the diagnostic characters for the various parts of the flower head of *Chrysanthemum cinerariæfolium*, which may be summarized as follows:

Fragments of the bracts: Epidermis striated and provided with numerous stomata, T-shaped hairs, and oil glands; under the epidermis of the central part there is a very characteristic fibrous hypoderma; the margins are very thin, and bear numerous T-shaped hairs.

Corolla of the ligulate florets: Upper (inner) epidermis characterized by being papillose over the whole surface, and by the sinuous striated cells of the lower (outer) epidermis.

Corolla of the tubular florets: Epidermis papillose near the apex but smooth over the remainder of the corolla, the latter portion consisting of regular cells containing rosette crystals of calcium oxalate.

Calyx of the tubular florets: Tissue of the calyx strengthened by the presence of numerous elongated, lignified cells. At the junction of the calyx with the ovary there is a disc composed of large, very irregular cells, with thick, lignified, pitted walls. Many of these cells contain prismatic crystals of calcium oxalate, one in each cell.

Ovary: Epidermis of the intercostal depressions is characterized by the presence of numerous oil glands and clinorhombic crystals. There is a lignified hypoderma similar to that of the lower part of the calyx. Walls of the ovary contain very large ducts filled with a brown granular secretion.

Anthers: Filaments consist of regularly arranged square cells; pollen grains, tubercular, having 3 pores.

Style: Cells of apex papillose; those of the stigma present a scale-like arrangement.

Receptacle: Characterized by large, rounded, pitted cells.

Peduncle: Débris furnished with T-shaped hairs and oil glands.

Hart (119) has called particular attention to the large number of translucent particles which he found in the ray florets. They occurred in every part of the flower head, except the bracts, but were most numerous in the ray florets. When treated with osmic acid they darkened very slightly, if at all, but when treated with an alcoholic solution of alkannin they turned red, which proved them to be resinous.

Schrenk (249) observed that the stems of the flower heads of *Chrysanthemum cinerariæfolium* (furnishing the Dalmatian flowers) consisted of collenchyma tissue which exceeded in amount the bast and woody tissues of the fibro-vascular bundles. Therefore fragments of collenchyma cells would be present in proportion to the amount of stems present, being very sparse in a good powder. The use of chloriodid of zinc was recommended for their detection. Schrenk found the scales of the involucre to be stiffened on the outer side and on both sides of the midrib by a coherent layer of sclerenchyma cells, many of which were elongated, having oblique or pointed ends and being joined in the manner of prosenchyma cells. These were usually found as fragments in the powder, and could be recognized by their walls pierced with narrow canals. He also observed these fragments to be much more numerous in the Persian than in the Dalmatian powder. He explained this by the fact that the greater portion of the very rigid, greenish, involucral scales (with the exception of the dark, reddish-brown scarious margin) consisted of sclerenchyma cells. Numerous hairs of a very characteristic structure were found on the outer surface and along the membranous edges of the scales of the Dalmatian flowers and on the flower stems as well. Each of these hairs consisted of a long cell with attenuated ends, placed horizontally on a 1 to 3 celled stalk arising from the epidermis. The terminal horizontal cell was bent and twisted in various ways, rather hooked at the end and forming feltlike layers, especially on the outermost scales.

Schrenk detected few hairs in the Persian flower insect powder which he examined. The flowers of *Chrysanthemum roseum* which he subsequently examined were almost entirely glabrous, with the exception of the hairs found where the stem widens into the receptacle, as well as at the base of the outermost scales. The hairs were of the same structure as those found on *Chrysanthemum cinerariæfolium*, only the terminal cells were much longer. He considered the papillæ covering the upper epidermis the most conspicuous among the fragments of the marginal corolla. These were not regarded as diagnostic, since the petals of other related species are similarly constructed. Stomata were remarkably numerous on the lower side of the marginal corolla. He did not find the insect flowers raised in California (Buhach), which belong to *Chrysanthemum cinerariæfolium*, any different in structure from flowers grown in their native country.

Kirkby (156) and Verneau (285) have called attention to one distinction which they believed might aid in identifying the Persian powder. They found the papillæ of the ray florets to be larger than those of the Dalmatian florets, thickened somewhat more at the apex, and with sides making a wider angle. Malfatti (186) has gone into the description of the Caucasian (*Chrysanthemum roseum*) flowers quite extensively, figuring the various parts of the flower head. Siedler (258) describes the physical characteristics of powders made from different parts of the flower.

MICROSCOPIC EXAMINATION OF INSECT POWDER.

Before attempting the critical examination of a commercial insect powder, the microscopist should become thoroughly familiar with the various parts of the insect flower head, in the whole as well as in the powdered condition. It has been found advantageous to sep-

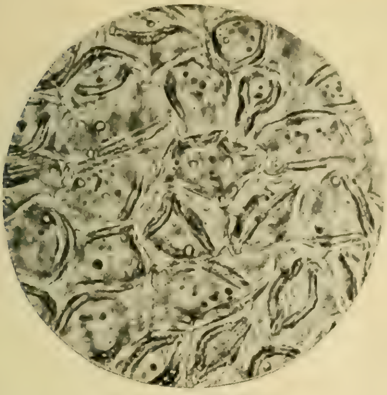

FIG. 1.—"PUCKERED" PAPILLÆ, RAY FLORET. (×290.)

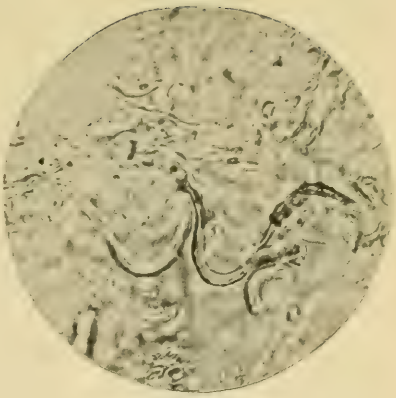

FIG. 2.—MARGINAL PAPILLÆ, RAY FLORET. (×210.)

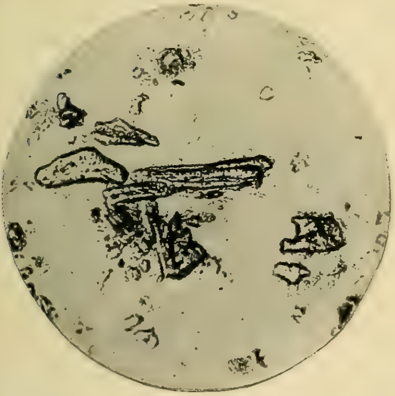

FIG. 3.—STONE CELLS, ACHENE.

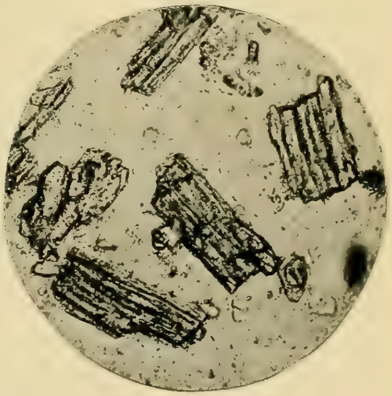

FIG. 4.—ACHENE TISSUES.

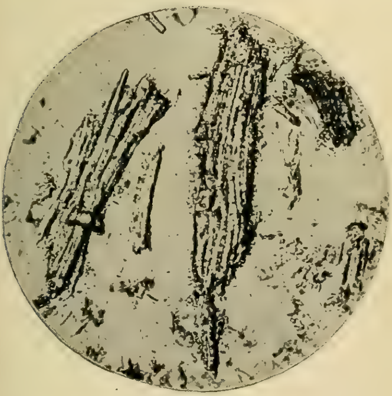

FIG. 5.—BRACT TISSUES. (×120.)

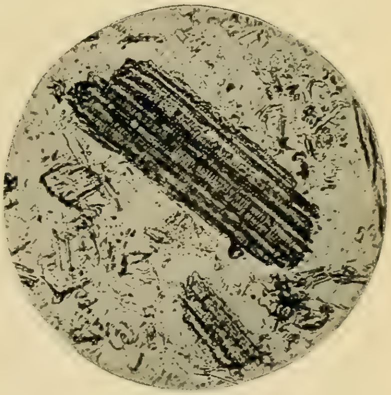

FIG. 6.—STEM TISSUES. (×84.)

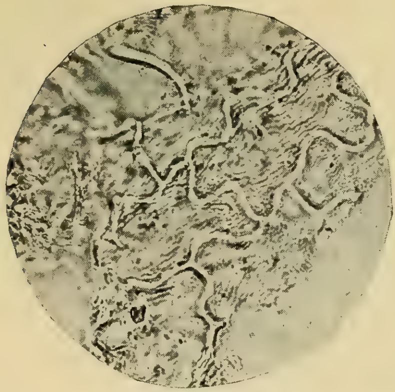

FIG. 1.—SINUOUS CELLS, RAY FLORET. (×254.)

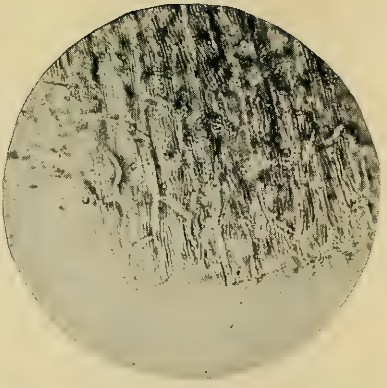

FIG. 2.—STRIATED CELLS, RAY FLORET. (×290.)

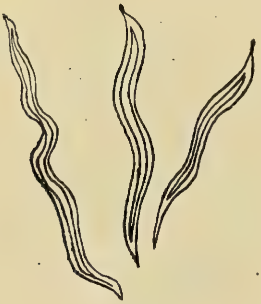

FIG. 3.—TWISTED HAIRS FROM BRACT. (×84.)

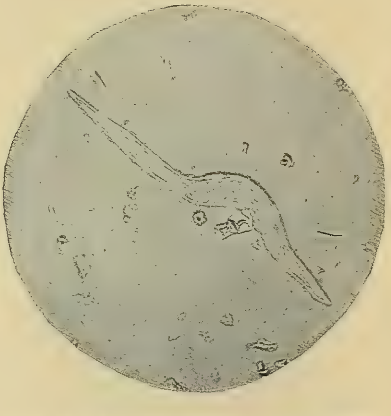

FIG. 4.—STALKED HAIR. (MAGNIFIED.)

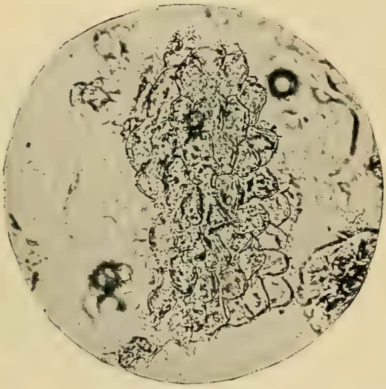

FIG. 5.—PAPILLÆ, RAY FLORET. (×140.)

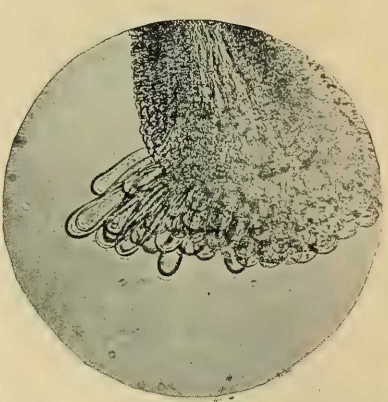

FIG. 6.—PORTION OF STIGMATIC LOBE. (×130.)

arate the disc and ray florets, the achenes and bracts, grinding them separately to the average fineness of a commercial powder. A study of these powders ground from the separate parts of the flower head will enable one to readily recognize them in a commercial sample. Powders ground from closed and open flowers should also be examined. The closed-flower powder is rich in the spiny, 3-pored pollen grains, and should not contain an excessive amount of sclerenchymatous tissue. The presence of considerable sclerenchymatized tissue usually indicates very mature (open) flower heads. The powder of open flowers does not contain as much pollen, but tissues from the achene are present in appreciable amount (Pl. IV, figs. 1 and 2).

The powder to be analyzed microscopically should be thoroughly mixed. This is best done by spreading the sample upon a sheet of white paper and mixing the powder with a spatula. Flattening the powder out upon the paper often reveals the presence of whole unground pieces of material which can be transferred to a microscopic slide and examined. After mixing, a composite sample is taken from various parts of the sample. A small amount of the powder is placed upon a microscopic slide, a drop or two of distilled water added, and the cover glass adjusted. If examination of the water mount reveals the presence of any foreign starch, a small amount of a solution of iodin in potassium iodid is drawn under the cover glass. This reagent stains blue any starchy material that may be present. For further examination a small portion of the powder should be mounted in chloral hydrate solution and gently heated over the flame. This solution serves to dissolve any starch that may be present, and clears the tissues generally. Until the microscopist has become thoroughly familiar with the Pyrethrum tissues, standard samples ground from the various parts of the flower head should be kept on hand for comparative study.

Siedler (258) employed phloroglucin and hydrochloric acid in detecting the presence of lignified tissues (vanillin reaction). On applying these reagents to disc-flower powder very little lignified tissue was evident, although pollen grains and fragments of papillate cells were numerous. The powder from the involucre showed a large number of woody elements, isolated vessels, thick-walled prosenchyma cells, scleroids, and pitted parenchyma cells. The short-stalked T-hairs were characteristic of this powder. The ray-flower powder exhibited very little lignified tissue, but a large number of papillate fragments, the cuticle layer, and large epidermal cells which were characterized by their striated surface. The powder from the receptacle showed small, yellowish-brown cells which did not give the vanillin reaction. Thin-walled, porous cells were numerous, also lignified prosenchyma cells and large isolated vessels.

Frequently the analyst is called upon to make an estimation of the approximate quantity of insect flower stems that may be present in a powder. The fragments of stem tissue, occurring to some extent in every insect powder, are readily distinguished from the other tissues present. The stems, when ground, invariably break up into longitudinal sections. Cross sections seldom appear in the powder. These long strands of collenchyma cells, fibers, and vascular elements have a characteristic appearance, possessing brushlike or slightly frayed ends, differing very much from the shredded appearance of the fragments of bract tissue. For the purpose of estimating the percentage of stem tissues present in a powder, it has been found convenient to make up standard powders, containing known amounts of ground stem tissues, to be used for comparison with the commercial samples. Mounting the powder in xylol often facilitates the detection of stem tissues. The patches of involucral tissue are invariably quite torn and coarsely shredded, and not in the long, smooth pieces characteristic of the stem tissue. The fruit (achene) tissue of the Dalmatian flowers occurs in squarish patches of short, thick-walled sclerenchyma cells, containing numerous crystals, many of them diamond-shaped. These crystals exhibit a variety of colors under polarized light, and are a means of distinguishing the Persian from the Dalmatian flowers, the Persian flowers lacking these crystals in the achene tissues.

Microscopically some differences exist between the Persian and Dalmatian powders. As has already been mentioned, the marginal papillæ are somewhat different in the two species, although this character would not be recommended as a final means for distinguishing between the two. The two varieties of flowers are much more easily distinguished from each other in the whole form than in the powder.

HISTOLOGY OF POWDER ELEMENTS.

Powder, when pure, is a golden yellow, turning bright yellow when mounted in potassium hydroxid (or other alkaline) solution. Japanese powders appear to be more yellow and aromatic than other commercial powders, and assume various greenish or ashen hues, depending upon the amount of stems present. The pure powder possesses more or less of an aromatic odor. If stems are present in appreciable amount, the powder tends to have a characteristic sage or tealike odor.

Phloroglucin and hydrochloric acid are useful in determining the amount of lignified tissue present. Lignified tissues assume a red coloration with these reagents. (Phloroglucin solution: 0.1 gram in 10 cc. of 95 per cent alcohol. Concentrated hydrochloric acid.) Potassium iodid solution of iodin turns starch a deep blue (0.05 gram

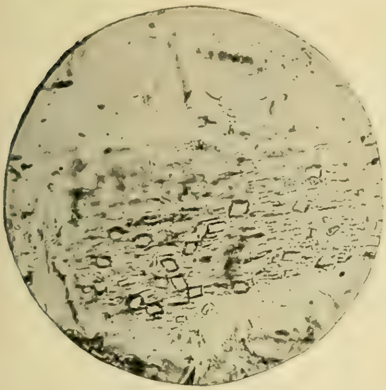

FIG. 1.—CRYSTALS, DISC FLORET. (×196.)

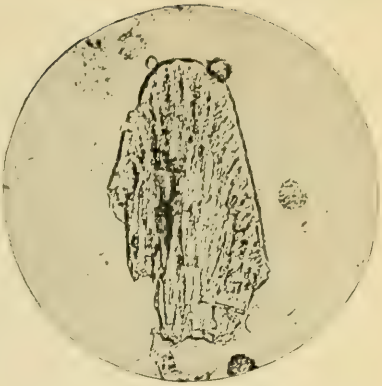

FIG. 2.—TOOTH, DISC FLORET. (×140.)

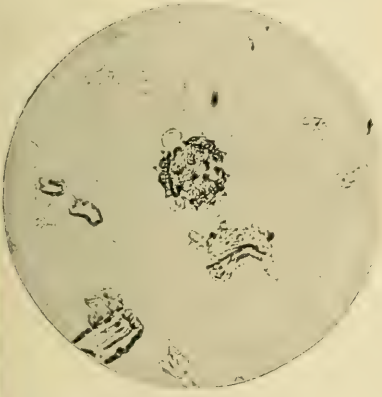

FIG. 3.—POLLEN GRAIN. (×290.)

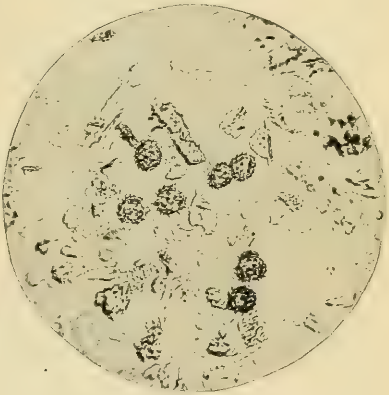

FIG. 4.—POLLEN GRAINS. (×140.)

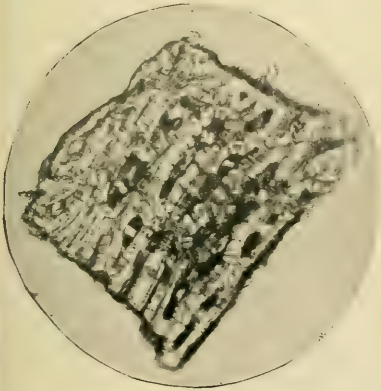

FIG. 5.—ACHENE TISSUE AND CRYSTALS. (×204.)

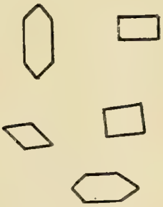

FIG. 6.—CRYSTALS FROM ACHENE. (MAGNIFIED.)

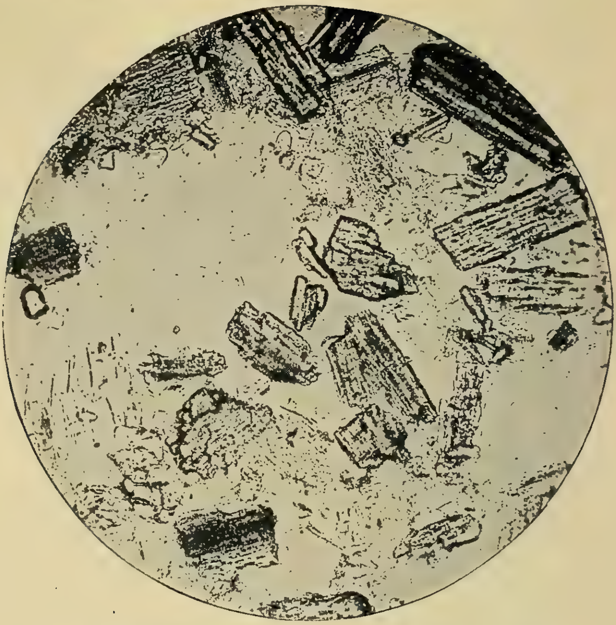

FIG. I.—POWDER FROM OPEN FLOWERS. (×72.)

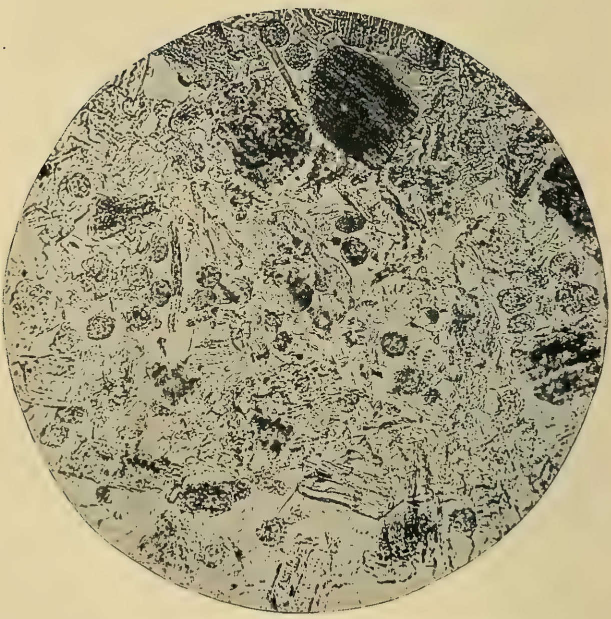

FIG. 2.—POWDER FROM CLOSED FLOWERS. (×72.)

of iodin and 0.2 gram of potassium iodid in 15 cc. of water). Chloral hydrate solution dissolves starch and clears the tissues (about 5 parts chloral hydrate in 5 parts of water).

DALMATIAN FLOWERS.

1. Numerous 3-pored, spiny pollen grains (Pl. III, figs. 3 and 4).
2. Marginal papillæ and papillæ in surface view presenting a "puckered" or 3-cornered appearance (Pl. I, figs. 1 and 2).
3. Sinuous, striated cells of epidermis of ligulate florets (Pl. II, figs. 1 and 2).
4. Toothed fragments of the disc florets (Pl. III, fig. 2).
5. Shredded fragments of involucral scales, strongly lignified (Pl. I, fig. 5).
6. Attenuated and twisted horizontal cells of T-shaped hairs from the bracts (Pl. II, figs. 3 and 4).
7. Occasional strands of stem tissue, much larger than other fragments, and usually possessing roughened or fibrous ends (Pl. I, fig. 6).
8. Oil glands from the corolla and fruit. These are very seldom detected in the powder.
9. Somewhat rectangular patches of sclerenchyma tissue from the fruit, containing numerous diamond-shaped crystals exhibiting a variety of colors under polarized light. Numerous isolated stone cells are also often found in powder ground from mature flower heads (Pl. I, figs. 3 and 4; Pl. III, fig. 6).

PERSIAN FLOWERS.

The diagnostic characters of the Caucasian or Persian flowers (*Chrysanthemum roseum*) in the powdered form are rather similar to those of the Dalmatian flowers. As already stated, the papillæ of the ray florets differ somewhat, and the achene tissues do not contain the crystals characteristic of the Dalmatian flower fruit. The reddish-brown scarious margins of the bracts are often more striking in the Persian powder than in the Dalmatian. Collin (47), who also studied the Persian flowers, has summarized the principal diagnostic characters which distinguish them from the Dalmatian flowers.

SUMMARY.

Of course, the relative abundance of many of the tissues mentioned depends upon whether the powder is ground from open or closed flowers. Pollen is more abundant in closed-flower powder and sclerenchyma tissues in open-flower powder. The greater part of the pollen of closed or immature flower heads still remains in the closed "buds" or heads, the pollen not having as yet been scattered by the wind. On the other hand, the mature flower heads are practically devoid of any great amount of pollen, but contain the mature achenes, or fruits, still attached to the receptacle, or, very often, fallen out, depending upon the ripeness of the heads. Consequently appreciably little of the achene or fruit tissues is found in closed-flower powder, while powder ground from open flowers is rich in the lignified tissues of the fruit and quite devoid of pollen grains.

Stem tissues occur in all powders to some extent, although they should not be present in excessive amount. Careful study of the stem tissues and the tissues of the flower head will show that there is not the slightest difficulty in distinguishing between them.

The following references in the bibliography (p. 83) deal with this subject: 23, 24, 29, 47, 69, 106, 115, 116, 117, 118, 119, 137, 148, 150, 152, 156, 162, 163, 169, 174, 186, 199, 202, 246, 249, 257, 258, 261, 278, 279, 281, 282, 285, 289.

CHEMICAL METHODS.

In all of the published work relating to the chemical analysis of insect powder the determinations have been practically confined to those of ash and of ether-soluble material, together with specific tests for turmeric, lead chromate, and other adulterants, the presence of which might be suspected. The active principles of the powder being unknown, a comparison of the contents of the ash, ether extract, etc., of the sample undergoing examination with those of powders of known purity has afforded the only method of judging the genuineness of a commercial powder by chemical means.

The first published analyses of insect powders are those reported in 1879 by Hilgard (131), who determined the ether extract of 4 samples with the results shown in Table 4.

TABLE 4.—*Ether-extract content of insect powder (Hilgard).*

Product.	Ether extract.
	Per cent.
"Persian Insect Powder"	9.5
"Buhach" (sample grown in 1878)	6.1
"Buhach" (sample grown in 1879)	5.8
"Lyon's Magnetic Powder"	4.9

His tests of these extracts on insects showed that the amount of the extract present was not necessarily a measure of the efficiency of the powder.

Grote (108), in 1880, found lead chromate in a sample of insect powder. He regards the odor of an insect powder as furnishing more evidence of its genuineness than the color. Kral (164), in 1880, found curcuma in a series of insect powders, but no lead chromate. Howie (139), in 1883, reported the results of the chemical examination of 12 insect powders. He considered the chemical method for the detection of added coloring matter as more accurate than the microscopic method. The results obtained on these 12 samples are shown in Table 5.

TABLE 5.—*Chemical examination of insect powder* (*Howie*).

Sample No.	Vendor's definition.	Color.	Adulterant.	Ash.
				Per cent.
1	Insect powder	Drab	Genuine	6.2
2	do	do	do	7.1
3		Olive drab	do	6.0
4	From closed flowers	Yellowish	do	6.8
5	All closed flowers	do	do	6.2
6	Open flowers	do	do	6.2
7	Packet powder	Yellow	Chrome	10.5
8	do	do	do	9.6
9	Opt	do	do	9.2
10	All closed flowers	do	Turmeric and chrome	8.0
11	Foreign	do	Chrome	9.4
12	Dalmatian	Very yellow	Turmeric	6.0

An anonymous writer in 1884 (13) suggested testing insect powder with ammonia water, which would cause an artificially colored powder to turn a more or less dark brown, while an uncolored powder would change only slightly. Exposed to direct sunlight a genuine powder in the course of a few hours loses its color, according to this writer. Meyer (202), in 1887, proposed to test for mineral impurities in an insect powder by shaking the sample with chloroform, which would cause the powder to rise to the top of the liquid, while the inorganic substances would settle to the bottom.

In 1888 Hart (119) found an ash content of from 6.10 to 6.40 per cent in samples of insect powder and one of from 5.40 to 6.10 per cent in insect flowers. The ash content of the peduncles and receptacles of the flowers was 5.60 per cent. Beringer (29), in 1889, made the determinations given in Table 6 on flowers of the *Chrysanthemum cinerariæfolium* and of the Hungarian daisy (*C. leucanthemum*).

TABLE 6.—*Chemical analysis of flowers of C. cinerariæfolium and C. leucanthemum* (*Beringer*).

Product.	Determination.				
	Petroleum-ether extract.	Ether extract.	Alcohol extract.	Water extract.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Chrysanthemum cinerariæfolium	2.49	2.85	6.57	16.70	6.50
Hungarian daisy	3.37	2.68	9.45	13.43	9.30

Beringer stated that no difference could be detected between the two powders by microscopical examination.

Unger (282) reports certain results of examination of Pyrethrum flowers (Table 7).

TABLE 7.—*Chemical analysis of Pyrethrum flowers and powder (Unger).*

Sample No.	Product.	Determination.			Remarks.
		Moisture.		Ash on water-free basis.	
		Dried over H_2SO_4.	Loss at 100°.		
		Per cent.	*Per cent.*	*Per cent.*	
1	Closed Dalmatian flowers	7.02	8.4	7.67	Much manganese present.
2	do	12.08		6.89	Do.
3	Open Dalmatian flowers	11.45		6.04	Do.
4	Insect powder	5.49		7.07	Do.
5	Closed Dalmatian flowers	10.29	10.81	7.12	Do.
6	Powdered closed Dalmatian flowers	6.76		7.56	
7	Dalmatian insect powder	5.39		6.21	Do.

Three samples of flowers, 2 of *Pyrethrum roseum* and 1 of *P. caucasicum*, grown near Berlin, were examined, the results in Table 8 being secured.

TABLE 8.—*Chemical analysis of insect flowers grown near Berlin.*

Sample No.	Product.	Determination.		Remarks.
		Moisture (loss at 100°).	Ash on water-free basis.	
		Per cent.	*Per cent.*	
1	Flowers of *P. carneum*	8.3	8.18	Much iron present, but no manganese.
2	Flowers of *P. caucasicum*	5.67	7.92	Iron (0.19 per cent) present.
3	Flowers of *P. carneum*	4.88	10.21	

Unger (282) reports the analyses given in Table 9 for adulterated insect powders.

TABLE 9.—*Chemical analysis of adulterated insect powders (Unger).*

Sample No.	Product.	Ash.	Remarks.
		Per cent.	
1	Insect powder	6.61	Stems present; almost no pollen grains.
2	do	9.7	Curcuma and stems present; pollen grains few.
3	do	7.3	Curcuma present; no manganese.
4	do	7.93	Barium chromate and many stems present; no pollen grains.
5	do	8.33	Lead chromate and many stems present; few pollen grains.
6	do	7.39	Very little manganese; curcuma present.

In another place (282, p. 167) Unger has recorded the results shown in Table 10.

TABLE 10.—*Chemical analysis of insect powders and flowers from Dalmatia* (*Unger*).

Sample No.	Product.	Determination.		Remarks.
		Moisture.	Ash on water-free basis.	
		Per cent.	*Per cent.*	
1	Insect powder	8.56	8.33	No manganese; barium chromate and stems present.
2	....do			Do.
3	....do		7.3	No manganese; much iron.
4	Flowers from Spalato	8.44	6.74	Strong in manganese.

From the fact that he found no manganese in Pyrethrum stems, while it was always present in the flowers, Unger proposed to determine whether a powder was strongly adulterated with stems by testing for manganese. Thoms (274), in 1890, however, found manganese in the ash of *C. leucanthemum* and *P. indicum*, and Siedler (258) showed that Pyrethrum stems are not entirely manganese-free. Appreciable quantities of manganese in Pyrethrum stems from Japan have been found by the authors.[1] Unger's test is of no value.

Thoms (274), in 1890, reported an ash content of 6.93 per cent in whole flowers of *C. cinerariæfolium*, and one of 6.94 per cent in the same after powdering. He (275) would determine the value of an insect powder by a determination of its ash and petroleum-ether extract, together with a microscopical examination. From Dalmatian insect powder which had been dried at 100°, Thoms obtained by extracting with petroleum ether 5.34 per cent of a brown-yellow extract (dried at 80°), which had a strong odor of insect powder. Other powders gave from 5 to 3.89 per cent. An adulterated insect powder gave only 3.83 per cent extract, without the characteristic odor. Flowers of *Chrysanthemum leucanthemum* (Hungarian daisy) yielded 4.02 per cent extract.

The Chemist and Druggist for March 22, 1890 (17), reports an ash content of 6 per cent on a sample of insect powder prepared from flowers grown in Gippsland, the southeastern district of Victoria, Australia.

Eymard (77), 1890, gives the analysis of Pyrethrum powder shown in Table 11.

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[1] Manganese was determined in the various grades of insect flowers and stems of both Dalmatian and Japanese origin, the following average amounts being found: Japanese stems, 0.0123 per cent; Dalmatian stems, 0.0077 per cent; Japanese closed flowers, 0.0155 per cent; Dalmatian closed flowers, 0.0096 per cent; Dalmatian open flowers, 0.0076 per cent. The manganese content of both stems and flowers varies so greatly and differs so little in the two parts of the plant that any method for estimating the amount of powdered stems in an insect powder from a determination of its manganese content is valueless.

TABLE 11.—*Analysis of Pyrethrum powder (Eymard).*

Essential oil	Small amount.
Bodies soluble in ether (5.60 per cent) composed of:	
Fatty bodies (per cent)	3. 80
Resinous bodies (per cent)	1. 80
Bodies soluble in alcohol (94.4 per cent (sic)) composed of:	
Brown resin (per cent)	4. 80
Plant albumen (per cent)	1. 75
Gummy substances (per cent)	14. 75
Inulin and soluble amidon (per cent)	8. 50
Mineral salts (per cent)	7. 88
Woody matter, by difference (per cent)	56. 72
Total (per cent)	100. 00
Mineral matter:	
Potassium chlorid (per cent)	1. 94
Calcium carbonate (per cent)	4. 15
Calcium phosphate (per cent)	0. 17
Iron and silica (per cent)	1. 62
	7. 88

Thompson (273) gives the results of the analysis of a number of "genuine" insect powders (Table 12).

TABLE 12.—*Analysis of "genuine" insect powder (Thompson).*

Sample No.	Color.	Ash.
		Per cent.
1	Fawn	6. 5
2	Yellowish brown	6. 6
3	Light yellowish brown	6. 9
4	Light fawn	6. 59
5	Light yellowish brown	6. 2

Of two samples which contained lead chromate, one was deep yellow, with 12.6 per cent of ash, while the other was dark yellow, with 26.8 per cent of ash.

Gehe & Co. (92) give the following results of the analysis of a sample of insect powder from Dalmatia: Soluble in alcohol, 26.35 per cent; insoluble in alcohol, 56.27 per cent; water, 8.45 per cent; ash, 8.93 per cent. As they themselves state, this analysis is worthless in determining whether the sample is genuine or not.

Hill (132), 1894, stated that genuine Dalmatian insect powder has a greenish-yellow color, possesses a characteristic tealike odor and a slightly bitter, aromatic taste, and shows on analysis from 8 to 10 per cent of moisture, and from 6.5 to 7 per cent of ash which is almost entirely soluble in hydrochloric acid.

Dieterich (69) records analyses of a number of samples of insect powders, including a determination of the maximum size of the particles in microns. He sets the following limits for a good commercial insect powder: Maximum size, 255 microns; moisture, 5.55 to 13.95 per cent. In the Erstes Dezennium der Helfenberger Annalen, 1886–95 (page 420), as the average of all determinations made on insect powders during that period, the following are given as the limiting values: Moisture (loss at 100°), 5.55 to 13.95 per cent; ash, 6.07 to 8.70 per cent; potassium carbonate in ash, 28 to 38.33 per cent; maximum size of particles, 109.44 to 175.50 microns.

TABLE 13.—*Chemical analysis of insect powders* (*Dieterich*).

Sample No.	Year.	Determination.			Maximum size of particles.
		Moisture (loss at 100°).	Ash.	K_2CO_3 in ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Microns.*
1	1896	9.55	8.35	23.47	179.55
2		8.25	7.65	31.57	255.15
3		11.18	7.58	30.96	151.20
1	1897	12.12	7.38	33.80	190.35
2		9.53	6.61	38.05	139.05
3		11.12	7.45	17.01	153.90
4		10.60	6.80	33.51	141.75
1	1900	11.26	8.06	....	148.50
2		6.95	6.40	....	311.85
3		....	7.13	....	302.40
4		9.93	7.56	....	141.75
5		9.33	8.75	....	155.25
6		....	6.38	....	155.25
7		7.43	6.90	....	198.45
1	1901	10.33	6.65	....	198.45
2		11.97	7.63	....	145.50
3		9.28	9.94	....	....
4		....	9.63	....	....
1	1902	7.97	7.01	....	202.50
2		8.83	6.39	....	135.00
3		10.52	6.16	....	67.50
1	1903	10.04	7.40	....	190.35
2		8.57	6.75	....	162.00
3		9.05	7.30	....	135.00
1	1904	8.81	6.35	....	162.00

In the Helfenberger Annalen for 1902 (page 186), Dieterich reports the results of the determination of the ether extract of insect powders, using the method of Fromme (85), in which 8 grams of powder are treated with 80 grams of ether of specific gravity 0.720 at 15° C., shaken at intervals during 1 hour, then 50 grams (=5 grams powder) shaken with 1 gram of water, filtered, the filter thoroughly washed with ether, and the filtrate evaporated and weighed. The extract of insect powders made in this way varied from 5.16 to 5.38 per cent.

Durrant (73) is the author of the ether extraction method that has been most generally applied in the valuation of insect powder. He proceeds as follows:

> Place 100 grains of the powder in the cylinder of a glass syringe (1 ounce). The powder should be pressed down compactly on to a piece of absorbent cotton to act

as a filter. Moisten with ether (0.735 sp. gr.); close the top of the syringe and macerate for 30 minutes; percolation may then proceed, the powder being repercolated with the same fluid four times, and finally washed through with sufficient ether to make up 1 fluid ounce. The resulting percolate should be of a rich yellow color; if a pronounced green color be the result the sample may be discarded at once.

This percolate should be evaporated at 200° F., and should weigh not less than 3.75 grains (=3.75 per cent), and should have the characteristic odor of the flowers * * *. Insect powder ground from selected closed flowers is sensibly free from chlorophyll, whereas traces of it (less than 0.5 per cent) will be found in powders prepared from mixed and half-open flowers, and in the foreign ground insect powders it often amounts to from 50 to 80 per cent of the total ether extract.

Durrant suggests the determination of the amount of chlorophyll when it is present in large amount, by converting it to glucose and determining that in the regular way. He concludes: "The value of insect powder is in direct proportion to the combined amount of essential oil and soft acid resin and in inverse proportion to the amount of chlorophyll—both statements to be read together."

Francis (84) determined the ether extract of a powder made from "ground flowers only," one from "ground stems only," and of a "mixture of these two in equal proportion," to be as follows: Ether extract of flowers, 6.07 per cent; ether extract of mixture, 3.82 per cent; ether extract of stems, 2.25 per cent. He states, "The ether extracts in each instance had a decided green color, indicating the presence of chlorophyll."

Dowzard (71) estimates ether-soluble matter as follows: "Two grams of the sample are mixed with 50 cc. of ether in a stoppered cylinder, the mixture being shaken at intervals during 2 hours; 25 cc. (=1 gram powder) of the clear ethereal solution is evaporated in a tared beaker and the residue weighed." He also makes use of physiological tests: "Two grams of the sample is transferred to a beaker, a cockroach is then introduced and the number of minutes which elapse before the insect becomes stupefied are noted." He gives the results of the examination of 12 samples shown in Table 14.

TABLE 14.—*Examination of insect powder* (*Dowzard*).

Sample No.	Period of physiological test.	Ether extract.	Sample No.	Period of physiological test.	Ether extract.	Sample No.	Period of physiological test.	Ether extract.
	Minutes.	*Per cent.*		*Minutes.*	*Per cent.*		*Minutes.*	*Per cent.*
1	4	8.4	5	5	6.4	9	7	5.0
2	5	7.6	6	5	5.6	10	8	3.2
3	5	7.4	7	5	5.4	11	12	4.2
4	5	6.6	8	5	5.0	12	12	3.0

Dowzard adds: "I think the figures prove that the value of insect powder as an insecticide is in proportion to the amount of ether-soluble matter present. Of course, it is impossible to obtain exact results with the physiological test because of the difference in size, health, etc., of the insects. In good samples of insect powder the ether extract varies between 5 and 9 per cent."

Dietze (70), of the firm of J. D. Riedel, Berlin, records numerous tests on insect powders (Table 15). He used powder ground by himself from closed flowers, and also commercial powders. Dietze prefers petroleum ether to ordinary ether as a solvent, as the former takes out the "active principle only," whereas ordinary ether extracts a number of other substances at the same time. In most cases the ether extract is more or less green, and has a less powerful odor than the petroleum-ether extract. Table 16 shows the results obtained upon various adulterants of insect powder.

Table 15.—*Chemical analysis of insect powder* (*Dietze*).

Sample No.	Determination.							
	Moisture (loss at 100°).	Ash.	On water-free basis.					
			Soluble in—					
			Ether.		Ordinary petroleum ether.	Purest petroleum ether.	Chloroform.	Equal mixture of chloroform and ether (0.720).
			Specific gravity, 0.735.	Specific gravity, 0.720.				
Powders prepared from closed flowers:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	7.43	7.68	9.38	7.41	....	....	7.02	6.81
2	3.42	8.26	8.59	....	....	....	....	....
3	5.51	8.28	7.27	....	....	....	....	....
4	8.10	7.37	8.14	....	....	....	....	....
5	6.16	8.34	8.23	7.74	....	3.68	....	....
6	7.41	6.70	6.44	4.35	2.50	2.61	....	....
7	6.95	7.70	6.46	5.24	3.15	3.12	....	....
8	4.55	7.77	6.78	5.01	2.93	2.69	....	....
9	8.90	6.65	6.78	5.78	....	3.35	....	....
10	7.23	6.75	6.71	5.01	....	2.83	5.26	5.17
11	9.85	7.08	7.41	4.88	2.76	2.02	....	....
12	8.48	7.67	6.59	4.49	2.60	2.46	....	....
13	8.06	7.49	6.12	5.92	3.03	2.97	....	....
Minimum	3.42	6.65	6.12	4.35	2.50	2.52	5.26	5.17
Maximum	9.85	8.34	9.38	7.74	3.15	3.68	7.02	6.81
Average	7.08	7.52	7.30	5.61	2.99	2.86	6.14	5.99
Commercial powders:								
1	8.33	6.85	4.34	2.98	....	1.53	....	....
2	7.76	6.58	4.66	3.15	....	....	....	....
3	9.15	9.08	7.28	5.12	....	2.64	....	....
4	7.03	8.37	5.19	4.97	2.48	2.29	....	2.83
5	7.63	8.14	6.09	4.52	....	2.64	....	....
6	7.88	6.83	6.87	4.04	3.03	2.91	4.87	5.19
7	11.79	6.63	6.03	4.29	2.48	2.38	....	....
8	8.68	7.36	8.68	5.17	3.47	3.29	6.03	5.86
9	9.20	6.94	8.51	6.17	3.09	2.81	....	....
10	6.70	8.10	6.18	3.52	2.07	....	....	....
11	8.62	7.45	4.41	2.41	1.60	....	....	....
12	4.55	10.89	3.72	3.43	2.79	....	....	....
Minimum	4.55	6.63	3.72	2.41	1.60	1.53	4.87	2.83
Maximum	11.79	10.89	8.68	6.17	3.47	3.29	6.03	5.86
Average	8.11	7.77	5.99	4.15	2.63	2.56	5.43	4.63

TABLE 16.—*Chemical analysis of insect powder adulterants (Dietze).*

Adulterant.	Determination.					
	Moisture (loss at 100°).	Ash.	Soluble in—			
			Ether.		Ordinary petroleum ether.	Purest petroleum ether.
			Specific gravity, 0.735.	Specific gravity, 0.720.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Johannesblumen von Chrys. Leucanthemum	7.59	8.22	3.76	3.17	2.46	2.25
Flor. chamom. vgl	10.39	12.72	7.51	4.96	4.69	4.14
Flor. chamom. Roman	6.78	8.65	10.06	5.34	4.09	4.05
Flor. chamom. Calendulæ	11.85	9.19	8.20	7.59	4.25	4.32
Lignum quassiæ	0.99	2.66	0.23	0.21	0.18	0.10
Folia sennæ	10.13	11.06	5.91	3.69	3.36	3.39

Dietze declares that the value of an insect powder can not be determined by any of these extraction methods, whether made with ether, petroleum ether, or chloroform, and the determination of ash and moisture, but that a practical test upon insects is necessary.

Fromme (85), in 1900, published results for ether extract determinations of from 6 to 7 per cent on half-opened buds and from 7 to 9.5 per cent on unexpanded buds. The ether extract of pure flowers is of a golden-yellow color, while that of the stalks is of a greenish tint, thus making it easy to detect such adulteration.

Haywood (121) gives the results of the chemical examination of a number of commercial insect powders shown in Table 17.

TABLE 17.—*Chemical analysis of commercial insect powders (Haywood).*

Product.	Determination.						
	Moisture.	Ash.	Ether extract.	Lead in ash.	Chromium in ash.	Barium in ash.	Turmeric.
	Per cent.	*Per cent.*	*Per cent.*				
Black flag insect powder	7.21	8.01	8.91	None	None	None	None.
Buhach	6.96	9.69	9.09	...do	...do	...do	Do.
Persian insect powder	5.82	12.02	5.15	Present.	Present.	...do	Do.
Pyrethrum insect powder	7.39	7.80	8.38	None	None	...do	Do.
Death dust for insects	6.75	7.74	10.68	...do	...do	...do	Do.
Pyrethrum powder	7.49	11.91	6.68	...do	...do	...do	Do.
Dalmatian insect powder	6.24	8.35	6.43	...do	...do	...do	Do.
Tiger insect powder	7.68	6.47	6.22	...do	...do	...do	Do.
Magic insect powder	6.47	5.90	6.35	...do	...do	...do	Do.
Insect powder	6.87	8.03	6.78	...do	...do	...do	Do.

Later, Haywood (122) gives the results of the examination of commercial insect powders for the presence of chromates. Chromium was determined quantitatively in the ash by titration with permanganate, and the values calculated to lead chromate. Of 105 samples examined, 19, or 18 per cent, were colored with lead chromate, the amount of which varied from 0.12 to 1.47 per cent.

Grieb (107) gives the ether-soluble matter of a number of insect powders. Nine samples obtained at different times from the same source gave ether-soluble matter from 7.3 to 12.4 per cent, while 5 samples from another source gave 7.0 to 12.0 per cent. Grieb makes a preliminary test with 1 gram of powder, shaking it with 10 cc. of ether in a test tube, and if, after settling, the ether is of a marked green color ("indicating the presence of ground stalks"), the assay is not proceeded with and the sample is rejected.

Jean (147), in his analysis of a number of samples of Pyrethrum powder, determined moisture, ash, "acidity," alcohol-ether extract, resinous substances, substances soluble in water, and the iodin absorbed by the water solution after rendering it alkaline by bicarbonate of soda (Table 18). In order to compare these results, Jean prepared a powder from genuine Pyrethrum flowers, called the "type" sample.

TABLE 18.—*Chemical analysis of Pyrethrum powder* (*Jean*).[1]

Sample.	Determination on dry basis.						
	Ash.	Acidity as H_2SO_4.	Alcohol-ether extract.	Resinous substances.	Soluble in water.	Iodin absorbed.	Moisture.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Type	8.90	1.00	24.03	9.30	14.73	3.86	....
A[2]	7.47	.99	24.94	8.01	16.93	7.65	11.5
B	10.04	1.09	30.47	13.76	16.70	5.22	9.9
C	8.70	.64	21.91	9.41	12.50	3.15	8.0
D	9.02	1.03	24.40	11.14	12.26	5.8	12.5

[1] Jean does not give his methods of analysis.

[2] Contained potassium chromate and sawdust.

Sato (236) states that mature flowers of the *Chrysanthemum cinerariæfolium* should be used in preparing insect powder. The most desirable moisture content is 7 to 8 per cent; the ash is 6 to 7 per cent, and always shows the reaction for manganese. The greater the content of ether-soluble matter, the greater the value of the powder. If the ether extract is green, leaves and stalks have been mixed with the flowers. The amount of ether extract should not be less than 6 per cent, and the ratio of ether extract to ash should be greater than 1. H. W. and S. C. Gadd (90) give methods for detecting turmeric and chrome alum in insect powder. For the determination of ether-soluble material they use Durrant's method. According to them the ash of a genuine powder should be of a light gray color and should not amount to over one-sixteenth of the original.

Vogt (286) in 1906 wrote that he invariably found a rich yellow percolate to be characteristic of the finest insect powders. He obtained 7.72 per cent of ether extract in a sample of insect powder ground by himself from closed flowers, and stated that samples of powders guaranteed by first-class houses to be ground from selected closed flowers have yielded from 7.13 to 10.25 per cent ether extract.

Evans Sons, Lescher and Webb (76) give the results shown in Table 19 on the ether extract determination of insect powders.

TABLE 19.—*Ether extract determination on insect powders.*

Year.	Labeled as—	Ether extract.
		Per cent.
1906	Closed flowers	8 to 9
1906	Open flowers	5 to 6
1906	Stalks	Up to 5
1907	Closed flowers	8.5 to 8.8
1907	Open flowers	5.8 to 6.2
1909	Powder from closed flowers	6.9
1909	do	6.6
1909	Powder from half-open flowers	5.9
1909	Powder from open flowers	5.2

One sample examined in 1909 gave only 4.3 per cent of an extract heavily contaminated with chlorophyll. Microscopical examination of the powder showed the presence of tissue derived from the stalk of the plant. Eight American commercial insect powders examined in 1910 contained from 3 to 4.8 per cent ether-soluble matter, the green color of the extracts indicating admixture of open flowers and stem tissues. A few foreign-ground powders examined in 1906 yielded from 2 to 3 per cent ether extract. The powders reported in Table 19, examined in 1906 and 1907, were of their own grinding.

Southall Brothers and Barclay in 1910 (268) reported finding from 7.57 to 8.28 per cent ether extract in authentic samples of insect powder when determined according to Durrant's method. Japanese flowers, mostly open, gave 13.98 per cent "resin" of an orange-brown color. In 1912 (269) they found 3.81 per cent of a deep-green extract in a specimen of insect powder said to be ground from stalks. Leubner (172), in 1910, found 5.59 per cent of a dirty-green extract in a sample of insect powder. He macerated the sample with an excess of ether for 3 hours, and dried the extract at 100°.

Cæsar and Loretz (43), in 1911, gave their method for the determination of ether extract of insect powder as follows: Seven grams of the air-dried powder are treated in a 150 cc. flask with 70 grams ether, macerated 2 hours, the mixture being frequently shaken up by hand, then filtered through a 9 cm. filter; 50.5 grams (=5 grams powder air-dried) of the filtrate are then evaporated in a 9 to 10 cc. porcelain dish over hot water, being careful not to set the dish on the ring of a steam bath, as the solution in that case will creep over the edge. The evaporation is carried to dryness, and the residue brought to constant weight in a desiccator. The extract should have a golden-yellow color and a characteristic, powerful odor, which should not resemble that of chamomile. This method is somewhat different from that given by them in 1898 (42), a slight modification of Durrant's test in which the extraction of the sample with ether was continued as long as the solvent took up anything, instead of exhausting with a specified quantity of ether. This method differs from that published by Fromme in 1900 only in the time of maceration, being two hours instead of one.

Cæsar and Loretz (42) found that insect powder made from closed flowers yielded from 8 to 9.5 per cent of extract, while open or partly open flowers gave 6.5 to 7.5 per cent. They state that the color of the extractions varies from pure yellow, dark yellow, and brownish yellow to greenish yellow, while that prepared from stems is of a dirty-green color, and the residue amounts to only 5.5 per cent. They state furthermore that the insecticidal properties of insect powder are fully represented in the ether extract, and are not due to any alkaloidal bodies that the powder may contain.

Linke (173) obtained the values shown in Table 20 on six authentic powders.

TABLE 20.—*Chemical analysis of authentic insect powders and whole flowers* (*Linke*).

Sample No.	Determination.		
	Moisture (loss at 100–105°).	Ether extract (Durrant's method).	Ash.
Powder:	*Per cent.*	*Per cent.*	*Per cent.*
1	9.08	4.28	7.04
2	9.64	5.48	7.52
3	7.20	[1] 5.56	7.64
4	6.66	5.22	
5	6.22	6.26	
6	5.24	5.56	6.56
Whole flowers:			
1	10.72		5.88
2	10.36		6.44
3	10.76		6.44

[1] 6.80 per cent when shaken continuously for 2 hours.

In the ash, the presence of iron, manganese, aluminum, calcium, magnesium, sodium, and potassium was shown, but in no instance was chromium found. After evaporating the ethereal solution the residue was dried at 100° C. for one hour before weighing.

Sattler (238) reports finding lead chromate in an insect powder, the ash of which was 6.105 per cent. Wiebelitz (293), 1912, found a lower ash content in two samples of insect powder than that usually reported, namely, 4.7 per cent and 5.1 per cent. Siedler (150), in 1912, obtained the results given in Table 21 on pure insect powder and on stem powder.

TABLE 21.—*Chemical analysis of pure insect powder and stem powder (Siedler).*

Product.	Determination.		
	Moisture at 110°.	Ash on air-dried material.	Ether extract.
	Per cent.	*Per cent.*	*Per cent.*
Pure insect powder	10.77	6.81 to 7.29	
Powder from best flowers			6.14
Stem powder	8.69	6.39	1.48
Unpowdered, but finely-cut flowers		6.36	

Siedler used ether with a specific gravity of 0.720, and, after completely extracting the sample in the cold, allowed the ether to evaporate spontaneously, and dried the residue for one hour upon the water bath. The color of the extract of the powdered flowers was dirty yellow, that of the stem powder green. With concentrated sulphuric acid there was no characteristic color reaction with either resinous residue. Siedler found the petroleum-ether extract of pure powdered flowers to be 4.01 per cent, and that of stem powder, 1.01 per cent. The flower extract was a pure yellow, that of the stems a pure green. With concentrated sulphuric acid the petroleum-ether extract from the flowers gave a deep green color, the stem powder a brown. He attempted to obtain a basis for analysis by means of the optical behavior of an alcoholic extract from flower and stem powders, but this extract proved to be optically inactive.

In 1913 Siedler (257) commented as follows on the chemical examination of insect powder:

> As the best criterion for the value of the insect powder is the determination of the ether extract, which was first made by Thoms. Later this method was modified in this way, that the powder was shaken with ether and an aliquot part of the decanted ether solution allowed to evaporate. This procedure has certain drawbacks. It is not possible to decant a definite quantity of ether solution without causing a difference in weight by evaporation of ether. Further, the ether solution can not be obtained clear except after long standing and it is very difficult to filter clearly. It always deposits fine dust after filtration. Finally, there is generally the feeling that the powder is not completely extracted through simple shaking, that a part of the ether-extractable material escapes determination.

In the same article Siedler gives results for the determination of ash in insect powders (Table 22). All these samples were ground from the best flowers free from stems, and had an average moisture content of 4 per cent. The total ash and the ash insoluble in dilute hydrochloric acid were determined on 2.5 grams of substance.

TABLE 22.—*Determination of ash in insect powder (Siedler).*

Sample No.	Total.	Insoluble in HCl.	Sample No.	Total.	Insoluble in HCl.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
1	8.6	0.1	6	8.0	0.1
2	7.7	.1	7	7.9	.1
3	7.0	.2	8	7.7	.1
4	7.0	.2	9	7.8	.1
5	7.9	.1	10	6.8	.1

Fromme (86) reports the ash content of insect powder as being between 6.5 and 9.5 per cent. In a later article (87) he criticizes the method of Trottner in which the number of pollen grains in 1 milligram of powder is estimated, and the value of the powder thus determined, the greater the number of pollen grains the better the powder. Fromme determined the ash and ether extract, observed the color and odor of the ether extract, counted the number of pollen grains in 1 milligram of powder, and made physiological tests with flies upon 7 samples of insect powder, with the result that some of the most active powders were shown to contain fewer pollen grains than other powders prepared largely from stems. The analytical results on these 7 samples are given in Table 23.

TABLE 23.—*Examination of active insect powder* (*Fromme*).

Ash.	Ether extract.	Color of ether extract.	Pollen grains in 1 mg.
Per cent.	*Per cent.*		
8.21	6.37	Golden yellow	308
7.17	6.00	Greenish yellow	2,415
7.25	6.15	Golden yellow	2,900
8.00	5.85	Greenish yellow	230
8.84	6.27	Golden yellow	3,000
8.00	5.01	Dirty green	710
7.10	3.40	Greenish	294

SUMMARY OF METHODS.

From the foregoing review of physiological, microscopical, and chemical methods for determining the genuineness of commercial samples of insect powder, it is seen that while satisfactory chemical or microscopical methods have been developed for detecting the addition of adulterants such as other species of flowers, curcuma, and Pyrethrum stems, these methods are not capable of accurately determining quantitatively the extent of this adulteration, although the amount of stems can be approximated by comparing under the microscope the unknown mixture with known mixtures of powdered flowers and stems. Of course, the amount of an inorganic adulterant, like lead chromate, may be accurately determined by chemical analysis, but such adulteration is now quite rare. Probably over 95 per cent of the adulteration of insect powder at the present time is with ground Pyrethrum stems.

One of the most promising microscopic methods for examining insect powder thus far proposed seems to be that of Trottner, in which the number of pollen grains in the weighed quantity of sample is estimated. This number, however, varies so in different powders of equal effectiveness as to prohibit a rigorous quantitative application of the method.

Kuraz has done more than anyone else in determining the relative effectiveness of insect flowers and stems by the method of testing against flies, but there is so much individual variation in the results by this method that its value is greatly lessened.

Of the chemical methods proposed the most valuable is the determination of the amount, and more particularly the color, of the ether extract. The amount of ether extract in flowers, however, varies markedly, as is also the case with stems, and its determination alone is not sufficient to enable the analyst to establish standards.

No element or compound that can be detected with the present methods of analysis is present exclusively in either the stem or flower of the Pyrethrum plant.

AUTHORS' METHOD.

As has been stated, the addition of ground stems of the Pyrethrum plant to the powdered flowers is at the present time the chief form of sophistication practiced. Since the amount of added stem can not be accurately determined quantitatively by the microscope, although it can be approximated, it occurred to the authors that a chemical method might be devised for measuring this form of adulteration. As long as the active constituent remains unknown, it is necessary to rely upon the determination of some essential constituent which occurs in the flowers in a reasonably definite amount and which is either absent or occurs in other parts of the plant in a widely different amount. Most of the constituents occurring in the flowers that can be accurately and readily determined occur also in all other parts of the plant, though in varying quantities. Nitrogen and phosphorus occur in the flowers in relatively large proportions, in comparison with the amount present in the stems, and upon these two constituents the most stress is laid. As indicated by investigations previously referred to, it may be true that the active insecticidal principle is soluble in ether and certain other organic solvents. Nevertheless, the efficiency of the product can not be measured by the amount of this ether extract as now determined, since many of the purest samples show a much lower ether extract content than some of those seriously adulterated. The color of the ether extract, which should be observed before evaporating off the ether, is of more value in determining the purity of the powder than the quantity of this extract. Its color should be yellow, with never more than a slight tinge of green.

For the purpose of securing data as to the chemical composition of Pyrethrum flowers and stems, a number of genuine samples were secured. Most of these samples have been the *C. cinerariæfolium*, the species commonly used in the United States at the present time for the production of insect powder. The three grades of flowers recognized by the trade, namely, "open," "half-open" ("half-closed"), and "closed," were secured. Samples of the commercial flowers, consisting of from 1 to 2 pounds of material, were obtained, and the percentage amounts of stems and dirt (including all matter other than flowers or stems) present were first determined. From the commercial samples of Pyrethrum stems the burrs, straw, and other foreign matter were removed and classified as "dirt." In each case 100 grams of the material, selected so as to accurately represent the whole sample, were used, and the separations were carefully made by hand. After separation of the extraneous material the flowers and stems were each ground to a powder for chemical analysis. (Owing to the small quantity of "dirt" and stems in the commercial flowers and to the small amount of dirt in the stems, it was found that these had little influence on the composition of the stems and flowers. The removal of this extraneous matter was therefore discontinued.)

Methods of Analysis.

Moisture.—Two grams of powder were weighed into an aluminum dish provided with a tight-fitting cover, and dried to constant weight in an oven heated by boiling water, *in vacuo*. When cooling in the desiccator and when weighing, the dishes were kept covered, so that the powder could not absorb any moisture from the air. It was found necessary to heat the powder from 8 to 10 hours before constant weight was reached. The loss in weight was reported as moisture.

Nitrogen.—This was determined in 2 grams of powder according to the official Gunning method.[1]

Ash.—Four or five grams of the sample were weighed into a platinum dish and slowly heated in an electric muffle furnace, finally at a dull red heat, until all the carbon was consumed. The residue was reported as ash. In practically all published methods for the determination of ash in insect powder, it is stated that the powder is simply ignited to constant weight. Such a method might give erroneous results, due to the presence of volatile potassium salts in Pyrethrum, which would be lost; also, ignition in the presence of organic matter would reduce phosphates. By using an electric muffle furnace all the carbon is consumed at a dull red heat; hence, these losses are practically prevented.

Ash insoluble in HCl ("sand").—The residue from the ash determination was transferred to a beaker, and digested with dilute hydrochloric acid (water 100 cc., HCl, sp. gr. 1.19, 15 cc.) for 2 hours on the steam bath, then filtered, washed, and the residue ignited and weighed. Since the ash in different samples varies, the ash insoluble in hydrochloric acid was calculated back to the original sample.

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[1] Jour. A. O. A. C., Vol. 1, No. 4, Pt. II, p. 7.

Phosphorus in the ash.—The filtrate from the last determination was made up to volume in a graduated flask, and phosphoric acid determined in an aliquot according to the official volumetric method (Jour. A. O. A. C., Vol. 1, No. 4, Pt. II, p. 3), allowing the solution to stand 30 minutes or longer at about 45°. The phosphorus, reported as P_2O_5, is calculated on the original sample. In many cases the P_2O_5 was determined gravimetrically (Jour. A. O. A. C., Vol. 1, No. 4, Pt. II, pp. 1–3).

RESULTS OF ANALYSIS.

TABLE 24.—*Examination of "closed" flowers (Chrysanthemum cinerariæfolium).*[1]

Sample No.	Source.	Stems.	"Dirt."	Determination.[2]				
				Moisture.	Nitrogen, N.	Ash.	Ash insoluble in HCl.	P_2O_5.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
12321[3]	Japan	1.00	0.25	4.50	1.58	6.80	0.67	0.715
12325	Europe	3.85	.75	4.65	1.83	7.84	.16	.728
12327	do	3.85	.15	4.40	1.74	7.38	.17	.622
12334[4]	do	6.25	.30	4.87	1.65	7.29	.15	.604
12335[3]	Japan	1.55	.15	4.62	1.72	7.09	.48	.709
14920	Europe	1.30	....	5.10	1.75	6.61	.33	.744
14921	do	2.70	....	5.70	1.92	7.12	.05	.740
14929	do	6.44	.38	5.51	1.65	6.12	.21	.754
14932[3]	Japan	.57	.11	5.71	1.64	6.19	.26	.729
14934	Europe	1.68	....	5.08	1.73	6.24	.11	.679
14938	do	.81	....	6.15	1.74	6.54	.36	.770
15009	do	3.08	....	5.94	1.80	7.43	.10	.743
15136[4]	do	5.05	....	7.55	1.87	7.69	.17	.815
17389	do	2.20	Trace.	....	1.69	6.97	.08	.624
17394[3]	Japan	1.12	Trace.	....	1.81	6.91	.24	.751
17395	Europe	1.54	Trace.	....	1.59	7.07	.13	.621
17621[4]	do	4.27	Trace.	....	1.85	7.36	.08	.706
17749	do	2.03	Trace.	....	1.78	7.70	.11	.591
17750	do	2.36	Trace.	....	1.73	6.86	.13	.659
	Minimum	.57	.11	4.40	1.580	6.12	.05	.591
	Maximum	6.44	.75	7.55	1.920	7.84	.67	.815
	Average	2.72	.30	5.37	1.741	7.01	.21	.700
	No. samples examined	19	13	13	19	19	19	19

[1] Practically all of the samples reported in this table were shipped from the port of Trieste, Austria.
[2] The flowers only were analyzed.
[3] Stated to be of Japanese origin and to have been repacked in Austria, but there is no proof of this.
[4] Imported as wild Montenegrin flowers.

TABLE 25.—*Examination of "closed" flowers (Chrysanthemum cinerariæfolium).*

Sample No.	Determination.[1]			
	Nitrogen, N.	Ash.	Ash insoluble in HCl.	P_2O_5.
Imported from Europe, supposedly of Dalmatian origin:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
12653	1.77	7.66	0.10	....
14752	1.55	6.25	.35	....
14991	2.00	7.91	.09	....
15271[2]	1.72	6.56	.33	....
15344	1.64	6.21	.26	....

[1] Results determined on the samples as received, including attached stems and the small amount of dirt present.
[2] Stated to be of Japanese origin.

TABLE 25.—*Examination of "closed" flowers (Chrysanthemum cinerariæfolium)*—Con.

Sample No.	Determination.[1]			
	Nitrogen, N.	Ash.	Ash insoluble in HCl.	P_2O_5.
Imported from Europe, supposedly of Dalmatian origin—Con.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
16260	1.54	6.29	0.26	....
16261	1.54	6.28	.30	....
17821	1.80	7.94	.13	....
18008	1.83	7.46	.09	....
18152	1.85	8.28	.31	....
18160[2]	1.77	8.22	.39	....
18376	1.95	7.74	.12	....
18548	1.86	7.54	.13	....
18598	2.09	8.06	.14	....
18724	1.82	7.61	.11	....
19055	1.82	8.15	.16	....
19175	1.67	6.72	.28	....
19179	1.71	7.42	.16	....
19284	1.91	7.52	.13	....
19286	1.92	7.73	.11	....
19288	1.89	8.06	.16	....
19924	1.79	8.03	.08	....
20188	1.75	7.08	.08	....
20189	1.60	7.14	.11	....
21208[3]	1.75	6.90	.64	....
21334	1.60	7.30	.15	....
21370	1.78	6.22	.28	....
21919	1.78	7.96	.13	....
22078	1.65	7.53	.21	....
22178	1.87	7.48	.09	....
22179	1.79	6.22	.39	....
22296	1.81	7.35	.18	....
22574	1.71	6.98	.43	....
22695	1.53	6.85	.14	....
22781	1.90	7.98	.86	....
23248	1.72	7.36	.91	....
Minimum	1.53	6.21	.08	....
Maximum	2.09	8.28	.91	....
Average (36 samples)	1.769	7.33	.24	....
Japanese origin:				
17927	1.69	6.36	.35	0.620
21163	1.74	6.27	.25	.758
21186	2.01	6.03	.19	.730
21439	1.84	6.68	.34	.642
21740	1.74	6.63	.41	.693
21840	1.94	6.16	.27	.663
22577	1.84	6.61	.29	.636
22698	1.78	6.99	.38	.697
22944	1.96	6.75	.28	.725
22949	1.66	6.95	.32	....
23247	1.65	6.48	.29	....
23438	1.72	6.67	.31	....
23772	1.61	7.41	.90	.729
23915	1.75	7.18	.42	....
24074	1.82	6.85	.65	....
24078	1.78	6.67	.29	....
24080	1.72	6.92	.68	....
24084	1.76	7.09	.79	....
24108	1.77	7.01	.74	....
24109	1.79	6.88	.47	....
24110	1.80	7.15	.82	....
24114	1.94	7.43	.97	....
24115	1.76	7.70	1.21	....
24116	1.73	7.19	.77	.684
24117	1.82	7.39	.97	.647
24118	1.76	6.96	.60	.624
24119	1.81	7.40	.98	.686
24120	1.81	7.26	.81	....
24121	1.88	7.33	.79	....
24298	1.80	6.81	.31	....
24368	1.74	7.13	.61	....
24625	1.84	8.58	2.03	.662

[1] Results determined on the samples as received, including attached stems and the small amount of dirt present.

[2] Stated to be wild Montenegrin flowers.

[3] Stated to be of Japanese origin.

TABLE 25.—*Examination of "closed" flowers (Chrysanthemum cinerariæfolium)*—Con.

Sample No.	Determination.			
	Nitrogen, N.	Ash.	Ash insoluble in HCl.	P_2O_5
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Japanese origin—Continued.				
24626	1.84	7.72	1.11	....
24627	1.91	7.46	.89	....
24628	1.87	7.50	.94	....
24629	1.82	7.63	1.05	....
24630	1.81	7.84	1.22	....
24631	1.80	7.72	1.34	....
24632	1.90	8.22	1.83	....
24633	1.70	7.28	1.04	....
24634	1.93	7.26	1.07	....
24635	1.90	8.31	1.77	....
24636	1.91	7.82	1.36	....
24637	1.98	7.68	1.15	....
24638	1.87	7.59	1.05	....
24639	1.84	7.37	.99	....
24640	1.91	7.12	.76	....
24641	1.77	7.22	.94	....
Minimum	1.61	6.03	.19	0.620
Maximum	2.01	8.58	2.03	.758
Average	1.813	7.18	.79	.680
No. samples examined	48	48	48	15

TABLE 26.—*Examination of "half-closed" flowers (Chrysanthemum cinerariæfolium).*

Sample No.[1]	Stems.	"Dirt."	Determination.[2]				
			Moisture.	Nitrogen, N.	Ash.	Ash insoluble in HCl.	P_2O_5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
12330	3.95	0.25	4.97	1.63	7.34	0.12	0.599
12331	5.05	.35	4.90	1.41	6.88	.45	.530
14926	2.90	....	6.40	1.74	6.97	.19	....
14935	1.16	....	6.44	1.55	....	....	....
17392	1.91	.14	....	1.75	7.60	.47	....
17419	0.62	....	....	1.58	6.14	.34	....
17620	2.28	....	....	1.74	6.88	.41	....
17673	2.22	.81	....	1.69	7.91	.21	....
18549	....	....	....	1.47	6.65	.31	.528
18603	....	....	....	1.48	6.63	.13	....
19056	....	....	....	1.40	7.57	.47	.592
19057	....	....	....	1.47	7.95	.74	....
20726	....	....	....	1.74	7.38	.50	....
21920	....	....	....	1.45	6.72	.15	....
22077	....	....	....	1.50	6.70	.23	....
22079	....	....	....	1.51	7.40	.35	....
22177	....	....	....	1.56	6.55	.10	....
22237	....	....	....	1.52	6.93	.10	....
Minimum	0.62	0.14	4.90	1.40	6.14	0.12	0.528
Maximum	5.05	.81	6.44	1.75	7.95	.74	.599
Average	2.51	.39	5.68	1.56	7.07	.31	.562
No. samples examined	8	4	4	18	17	17	4

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[1] All the samples in this table were imported from Europe and are supposedly of Dalmatian origin, except No. 20726, which was stated to be of Japanese origin.

[2] Where the percentage of stems is given, the chemical analysis was made on the flowers only; on the other samples the analysis was made on the material as received.

TABLE 27.—*Examination of "open" flowers (Chrysanthemum cinerariæfolium).*

Sample No.	Stems.	"Dirt."	Determination.[1]				
			Moisture.	Nitrogen, N.	Ash.	Ash insoluble in HCl.	P_2O_5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
12320	1.40	0.30	4.81	1.24	5.71	0.10	0.534
12323	1.70	.65	5.33	1.26	6.26	.23	.585
12324	3.10	.20	5.55	1.30	6.55	.17	.528
12329	3.50	.65	5.40	1.31	6.12	.16	.551
12332	2.75	.45	5.65	1.40	7.09	.35	.557
14923	4.51		6.13	1.31	6.42	.31	.593
14924	3.61		7.70	1.31	5.68	.13	.605
14927	2.45		7.41	1.26	5.61	.11	.550
14930	1.93		6.35	1.22	4.88	.09	.588
14936	2.87	.30	6.61	1.27	5.15	.09	.598
14939	1.97		6.82	1.33	7.06	.65	.618
14945	1.85		9.21	1.28	6.10	.28	.537
14961	2.91		7.10	1.26	6.15	.28	.586
14962	2.05		6.44	1.28	5.76	.17	.615
15008	1.79		7.65	1.24	5.68	.10	.588
15209	1.09		7.85	1.25	5.56	.08	.593
15270	1.60		7.69	1.25	5.97	.18	.507
17385	2.36	Trace		1.26	5.93	.26	.541
17388	2.48	do		1.23	5.89	.24	.510
17391	2.23	do		1.19	6.09	.26	.457
17393	2.14	do		1.27	6.63	.41	.453
17396	1.17	do		1.22	5.73	.23	.524
17418	1.50	do		1.26	6.11	.46	.485
17422	2.38	do		1.25	6.16	.31	.486
17623	1.53	do		1.25	6.97	.53	.562
17674	3.48	do		1.26	6.21	.39	.459
17751	2.28	do		1.18	5.28	.19	.518
17929	1.45	do		1.36	6.11	.29	.517
Minimum	1.09	0.20	4.81	1.18	4.88	.08	.453
Maximum	4.51	.65	9.21	1.40	7.09	.65	.618
Average	2.29	.43	6.69	1.268	6.03	.25	.544
No. samples examined	28	6	17	28	28	28	28

[1] Flowers only analyzed.

TABLE 28.—*Examination of "open" flowers (Chrysanthemum cinerariæfolium).*[1]

Sample No.	Stems.	Determination.			
		Nitrogen, N.	Ash.	Ash insoluble in HCl.	P_2O_5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
12459	3.40	1.25	6.10	0.13	0.537
12460	2.80	1.27	5.94	.08	.490
12652	2.70	1.17	6.29	.19	
12703	4.00	1.25	6.36	.11	
12790	1.90	1.27	5.72	.11	.459
12860	4.00	1.37	6.47	.50	.499
14383		1.26	6.08	.15	.517
14892		1.31	6.89	.47	.513
14977		1.23	6.17	.46	.451
15343		1.27	6.10	.22	.514
15530		1.24	5.76	.31	.462
15542		1.24	5.99	.23	
16377		1.20	6.33	.31	.528
16757		1.25	6.04	.32	
16863		1.26	5.84	.33	.546
16987		1.24	5.68	.24	.506
16998		1.30	6.39	.42	.595
17754	4.99	1.26	6.12	.42	.455
17822	1.28	1.23	6.06	.24	.497
17928	1.40	1.30	6.38	.27	.519
18003	2.34	1.23	5.57	.09	.566
18004	1.66	1.24	5.76	.34	.515
18005	.88	1.29	6.13	.08	.546
18006	.96	1.30	6.10	.08	.561
18007	1.30	1.30	6.84	.41	.507
18009	1.89	1.21	5.96	.08	.543
18010	2.26	1.23	5.83	.24	.512
17871	3.07	1.32	5.46	.17	.530
18117		1.22	5.69	.25	.460
18118		1.25	6.02	.13	.530
18150		1.24	6.74	.62	.490
18154		1.23	6.49	.49	.528
18377		1.25	5.96	.19	.483

[1] The results of analysis are on the material as received. The samples are of European origin.

TABLE 28.—*Examination of "open" flowers (Chrysanthemum cinerariæfolium)*—Con.

Sample No.	Stems.	Determination.			
		Nitrogen, N.	Ash.	Ash insoluble in HCl.	P_2O_5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18378		1.20	5.65	0.16	0.469
18379		1.34	6.19	.15	.549
18380		1.27	5.85	.13	.503
18381		1.19	5.73	.12	.472
18382		1.31	5.88	.20	.519
18547		1.19	5.22	.14	.515
18597		1.25	5.68	.09	.485
18599		1.28	5.73	.13	.531
18600		1.29	6.32	.28	.514
18601		1.27	5.76	.14	.547
18604		1.23	5.64	.09	.472
18725		1.23	5.38	.16	.541
19178		1.29	6.12	.22	.521
19240		1.24	5.83	.21	.608
19241		1.37	6.02	.22	.592
19285		1.33	5.96	.06	.532
19287		1.27	5.68	.18	.523
19290		1.31	6.28	.21	.595
19291		1.32	6.93	.37	.532
19292		1.38	6.53	.31	.554
19627		1.21	7.53	1.38	.561
19925		1.20	6.08	.25	.511
19926		1.21	5.01	.08	.505
20145		1.21	5.74	.27	.493
20436		1.23	5.64	.21	.592
20437		1.25	5.93	.09	.479
20438		1.31	5.91	.13	.508
20439		1.25	6.40	.37	.495
20440		1.19	6.24	.14	.501
20442		1.30	5.92	.14	.601
20443		1.18	6.19	.12	.559
20444		1.24	7.00	.30	.539
20446		1.38	6.80	.37	.568
21106		1.26	6.45	.26	.612
21184		1.32	5.95	.22	.667
21368		1.33	5.67	.14	.538
21918		1.25	5.36	.13	.576
22424		1,27	5.92	.09	
22694		1.37	7.87	.88	
22696		1.25	6.06	.20	
22697		1.36	7.57	.48	
22925		1.39	6.62	.10	
24302		1.28	6.66	.41	
Minimum	.88	1.17	5.01	.06	.451
Maximum	4.99	1.39	7.87	1.38	.667
Average	2.40	1.267	6.11	.25	.526
No. samples examined	17	76	76	76	66

TABLE 29.—*Examination of insect flower stems (cleaned) (Chrysanthemum cinerariæfolium).*[1]

Sample No.	"Dirt."	Determination.				
		Moisture.	Nitrogen, N.	Ash.	Ash insoluble in HCl.	P_2O_5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
12322		4.77	0.842	3.98	0.10	0.144
12326	Trace.	5.20	.695	4.00	.11	.151
12328		5.10	.842	5.00	.38	.200
12333		5.22	.856	4.69	.31	.247
12336		4.72	.863			
14922	4.37	5.34	.820	4.58	.38	.269
14925	8.27	4.51	.800	4.86	.27	.146
14928	1.06	5.79	.575	4.34	.15	.183
14931	.38	5.09	.800	4.63	.59	.169
14937	4.44	5.34	.960	5.44	.38	.256
14946	5.67	6.39	.800	4.29	.30	.236
14960	.96	5.69	.805	5.12	.34	.182
15010	1.35	5.26	.705	4.78	.18	.203
15137	8.89	7.20	.870	5.19	.41	.128
Minimum	.38	4.51	.575	3.98	.10	.128
Maximum	8.89	7.20	.960	5.44	.59	.269
Average	3.93	5.40	.802	4.68	.30	.193
No. samples examined	9	14	14	13	13	13

[1] All samples were imported from Europe.

TABLE 30.—*Examination of insect flower stems (commercial) (Chrysanthemum cinerariæfolium).*

Sample No.	Determination.			
	Nitrogen, N.	Ash.	Ash insoluble in HCl.	P_2O_5.
Imported from Europe (supposedly of Dalmatian origin):	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17397	0.677	4.83	0.38	0.191
17622	.725	4.06	.21	.212
17748	.674	4.61	.29	.185
17820	.877	4.78	.50	.191
17823	.940	4.26	.09	.145
18161	.779	4.74	.41	.166
18380	.589	4.19	.21	.137
18550	.568	4.11	.26	.150
19289	.772	3.94	.13	.190
20187	.835	5.01	.37	.190
20266	.582	6.03	.33	.117
24190	.877	6.70	.44	.345
24294	.547	3.60	.14	.257
Minimum	.547	3.60	.09	.117
Maximum	.940	6.70	.50	.345
Average	.726	4.68	.29	.190
No. samples examined	13	13	13	13
Japanese origin:				
21369	.610	3.40	.06	.125
22576	1.05	5.62	.34	.383
22936	.863	6.22	.72	.236
23773	.982	5.93	1.69	.338
24295	1.12	5.97	.69	.388
24369	1.10	6.24	1.41	.411
92	.982	5.03	1.10	.326
93	.814	5.58	1.50	.324
94	.954	5.07	.79	.347
95	.948	5.63	1.45	.336
96	.884	4.81	.90	.327
25087	.828	5.02	.80	.374
Minimum	.610	3.40	.06	.125
Maximum	1.120	6.24	1.69	.411
Average	.928	5.38	.95	.326
No. samples examined	12	12	12	12

TABLE 31.—*Nitrogen in stems picked from "open" flowers (Chrysanthemum cinerariæfolium).*

Sample No.	Nitrogen, N.	Sample No.	Nitrogen, N.
	Per cent.		*Per cent.*
12332	0.673	17422	0.620
14923	.674	17623	.740
14924	.590	17674	.620
14927	.702	17751	.700
14930	.646	17754	.590
14936	.730	17822	.786
14939	.730	17871	.730
14945	.646	17928	.650
14961	.702	17929	.670
14962	.730	18003	.646
15008	.954	18004	.730
15209	.710	18005	.842
15270	.790	18006	.823
17385	.650	18007	.748
17388	.700	18010	.646
17391	.700		
17393	.670	Minimum	.590
17396	.600	Maximum	.954
17418	.930	Average (34 samples)	.708

TABLE 32.—*Nitrogen in stems picked from "closed" flowers (Chrysanthemum cinerariæfolium).*

Sample No.	Nitrogen, N.	Sample No.	Nitrogen, N.
	Per cent.		*Per cent.*
14921	1.60	17749	1.52
14934	1.40	17750	1.52
15009	1.52	17821	1.57
15136	1.54	18008	1.63
17389	1.54		
17394	1.77	Minimum	1.21
17395	1.21	Maximum	1.77
17621	1.54	Average	1.53

It was found that a determination of the nitrogen and of the phosphorus, together with a qualitative ether-extract test (to determine its color), were sufficient to determine the presence and approximate percentage of stems.

In but few of the published analyses of insect powder, where ether extract is given as one of the determinations, is the kind of ether specified. In some methods the powder is simply shaken up with ether, filtered, and an aliquot evaporated. Dietze (70) has shown that the results do not agree when ether of specific gravity 0.720 and of 0.735 is used. Ordinary ether contains some alcohol and water and extracts from insect-powder material other than the active insecticidal constituents. For concordant results, the ether used in making the extractions must always be of the same grade. Anhydrous, alcohol-free ether would seem to be the best solvent to use.

Pyrethrum flowers usually yield an intensely yellow ether extract, whereas the stems give one of a strong green color. The odor of the extract from the flowers is also characteristic. In the examination of commercial insect powder the presence of a material amount of powdered stems can always be detected by the green color of the ether extract. Its quantitative estimation is, however, of little value in determining the amount of stems present, and this determination was made in only a few cases, the method employed being as follows: The 2 grams used in the determination of moisture were transferred to an extraction thimble and extracted in a suitable apparatus for 16 hours with ether that had been freshly distilled over metallic sodium. After extraction, the ethereal solution was evaporated to dryness on the steam bath and dried to constant weight at the temperature of boiling water.

The petroleum-ether extract was determined in a few cases by thoroughly extracting 2 grams of the powder in a Soxhlet apparatus with commercial petroleum ether (specific gravity, 0.640; boiling point, 30° to 65° C.), evaporating the extract on the steam bath, and drying for a few minutes in an oven at 100° C.

The petroleum-ether extract of flowers does not differ enough from that of stems to make this determination of value in arriving at the amount of stems present.

Pentosans were determined in a few of the samples, and it was found that the amounts in the different forms of flowers differed but little from each other and also but little from that in the stems.

The determination of crude fiber is of value in indicating whether or not the powder has been made from open or closed flowers. Pentosans and crude fiber were determined according to the methods of the Association of Official Agricultural Chemists (Jour. A. O. A. C., Vol. II, No. 1, Pt. II, pp. 52–53, 60–61).

TABLE 33.—*Determination of ether extract and petroleum-ether extract.*

Sample No.[1]	Determination.	
	Ether extract.	Petroleum-ether extract.
"Closed" flowers:	*Per cent.*	*Per cent.*
14920	....	4.75
14921	7.45	....
14929	7.18	5.03
14932	6.85	....
14934	5.99	3.05
14938	7.34	3.93
15009	6.41	3.80
Minimum	5.99	3.05
Maximum	7.45	5.03
Average	6.87	4.11
No. samples analyzed	6	5
"Open" flowers:		
14923	5.48	3.64
14924	5.73	3.98
14927	6.28	4.45
14930	....	4.70
14936	6.00	....
14939	....	3.53
14945	6.60	5.05
14961	5.35	3.50
14962	5.93	3.60
"Open" flowers—Continued.	*Per cent.*	*Per cent.*
15008	5.09	....
Minimum	5.09	3.50
Maximum	6.60	4.70
Average	5.81	4.06
No. samples analyzed	8	8
Stems:		
14922	3.15	1.95
14925	3.35	2.08
14928	2.88	1.93
14931	2.34	1.53
14937	3.98	....
14946	3.43	1.75
14960	....	2.78
15010	3.40	1.78
Minimum	2.34	1.53
Maximum	3.98	2.78
Average	3.22	1.97
No. samples analyzed	7	7

[1] All samples were obtained from Europe.

TABLE 34.—*Determination of pentosans.*

Sample No.[1]	Pentosans.
"Closed" flowers:	*Per cent.*
12321	17.75
12325	16.06
12327	16.18
12334	16.53
12335	16.80
Minimum	16.06
Maximum	17.75
Average (5 samples)	16.66
"Open" flowers:	
12320	21.42
12323	21.07
12324	21.72
12329	21.34
"Open" flowers—Continued.	*Per cent.*
12332	19.98
Minimum	19.98
Maximum	21.72
Average (5 samples)	21.11
Stems:	
12322	18.40
12326	18.78
12328	17.54
12333	18.40
12336	17.95
Minimum	17.54
Maximum	18.78
Average (5 samples)	18.21

[1] All samples were obtained from Europe.

TABLE 35.—*Determination of crude fiber.*

Sample No.[1]	Crude fiber.
"Closed" flowers:	*Per cent.*
12334	22.89
14921	18.65
14929	20.63
14932	19.80
14934	20.62
14938	20.03
17389	20.94
17394[2]	22.73
17395	21.96
17621	20.39
17749	21.61
17750	19.45
17927[3]	23.83
21163[3]	21.97
21186[3]	21.47
21439[3]	24.70
21740[3]	21.71
21840[3]	24.03
22577[3]	23.91
22698[3]	22.47
22944[3]	21.46
23772[3]	24.10
24116[3]	23.54
24117[3]	22.86
24118[3]	23.77
24119[3]	23.78
24625[3]	23.03
Minimum	18.65
Maximum	24.70
Average (27 samples)	22.09
"Open" flowers:	
12320	35.12
12323	30.13
12324	31.55
12329	29.79
12860	27.20
14936	33.11
14945	27.75
14961	29.48
14962	30.28
14977	31.18
15008	30.03
17393	29.17
17751	34.70
17754	29.48
17929	32.80
18547	30.13
19292	30.27
20145	32.23
20436	33.87
20437	27.63
"Open" flowers—Continued.	*Per cent.*
20438	32.54
20439	31.17
20440	30.11
20442	32.13
20443	31.99
20446	28.82
21184	29.96
21918	35.85
Minimum	27.20
Maximum	35.85
Average (28 samples)	31.02
Dalmatian stems:	
14925	34.55
14928	36.45
14931	33.54
14937	39.05
14946	35.43
17397	38.82
17622	38.92
17748	38.27
17820	39.71
17823	38.23
18380	38.61
18550	39.13
20187	38.10
24190	33.60
24294	42.98
Minimum	33.54
Maximum	42.98
Average (15 samples)	37.69
Japanese stems:	
21369	39.07
22576	46.19
22936	32.39
23773	46.12
24295	44.46
24369	42.99
24392	46.24
24393	47.45
24394	48.05
24395	47.31
24396	48.79
25087	43.49
Minimum	32.39
Maximum	48.79
Average (12 samples)	44.38
Average of all	40.66

[1] Unless otherwise indicated, all samples were obtained from Europe.
[2] Source unknown.
[3] Obtained from Japan.

The ash content is highest in closed flowers, next highest in open flowers, and lowest in the stems. A higher percentage of the ash of stems is insoluble in hydrochloric acid than in the case of the flowers, although calculated back to the original material the difference is slight. It is only when the ash and the ash insoluble in acid are markedly above the normal for flowers that much importance is attached to these determinations.

A striking thing in the figures for nitrogen and for phosphoric acid is that they run fairly constant for the same material (*Chrysanthemum cinerariæfolium*), no matter what its source. This uniformity in the amount of certain ingredients present in Pyrethrum flowers and stems aids the analyst to determine from the analysis of an unknown commercial insect powder whether or not it is adulterated with powdered Pyrethrum stems.

By the color of the ether extract and by a determination of the nitrogen, phosphoric acid, and crude fiber, together with a microscopical examination, the presence of powdered stems in insect powder can be shown qualitatively and an approximate determination of the amount of stems can be made.

Table 36 summarizes all the results for nitrogen, phosphorus pentoxid, crude fiber, ash, ash insoluble in hydrochloric acid, pentosans, ether extract, moisture, and extraneous material, for stems and the three commercial grades of flowers, of both Dalmatian and Japanese origin.

TABLE 36.—*Summary of examination of insect flowers and stems.*

Product.		Nitrogen, N.	P_2O_5.	Crude fiber.	Ash.	Ash insoluble in HCl.	Pentosans.	Ether extract.	Petroleum-ether extract.	Moisture.	Stems.	"Dirt."
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent*
Japanese "closed" flowers	Min..	1.61	0.620	21.46	6.03	0.19	......	......	......	......	......	......
	Max..	2.01	.758	24.70	8.58	2.03	......	......	......	......	......	......
	Ave..	1.813	.680	23.11	7.18	.79	......	......	......	......	......	......
No. samples examined..		48	15	15	48	48	......	......	......	......	......	......
Dalmatian "closed" flowers	Min..	1.53	0.591	18.65	6.12	0.05	16.06	5.99	3.05	4.40	0.57	0.11
	Max..	2.09	.815	22.89	8.28	.91	17.75	7.45	5.03	7.55	6.44	.75
	Ave..	1.759	.700	20.81	7.22	.23	16.66	6.87	4.11	5.37	2.72	.30
No. samples examined..		55	19	12	55	55	5	6	5	13	19	7
All "closed" flowers (Japanese and Dalmatian)	Min..	1.53	0.591	18.65	6.03	0.05	......	......	......	......	......	......
	Max..	2.09	.815	24.70	8.58	2.03	......	......	......	......	......	......
	Ave..	1.784	.691	22.09	7.20	.49	......	......	......	......	......	......
No. samples examined..		103	34	27	103	103	......	......	......	......	......	......
"Half-closed" flowers	Min..	1,40	0.528	......	6.14	0.12	......	......	......	4.90	0.62	0.14
	Max..	1.75	.599	......	7.95	.74	......	......	......	6.44	5.05	.39
	Ave..	1.566	.562	......	7.07	.31	......	......	......	5.68	2.51	.81
No. samples examined..		18	4	......	17	17				4	8	4
"Open" flowers	Min..	1.17	0.451	27.20	4.88	0.06	19.98	5.09	3.50	4.81	0.88	0.10
	Max..	1.40	.667	35.85	7.87	1.38	21.72	6.60	4.70	9.21	4.99	.90
	Ave..	1.267	.532	31.02	6.09	.26	21.11	5.81	4.06	6.69	2.33	.47
No. samples examined..		104	94	28	104	104	5	8	8	17	45	9
Japanese stems	Min..	0.610	0.125	32.39	3.40	0.06	......	......	......	......	......	......
	Max..	1.12	.411	48.79	6.24	1.69	......	......	......	......	......	......
	Ave..	.928	.326	44.38	5.38	.95	......	......	......	......	......	......
No. samples examined..		12	12	12	12	12						
Dalmatian stems	Min..	0.547	0.117	33.54	3.60	0.09	17.54	2.34	1.53	4.51	......	0.38
	Max..	.960	.345	42.98	6.70	.59	18.78	3.98	2.78	7.20	......	8.89
	Ave..	.733	.192	37.69	4.68	.29	18.21	3.22	1.97	5.40	......	3.93
No. samples examined..		6	26	15	26	26	5	7	7	14		9
All stems (Japanese and Dalmatian)	Min..	0.547	0.117	32.39	3.40	0.06						
	Max..	1.12	.411	48.79	6.70	1.69						
	Ave..	.765	.234	40.66	4.90	.50						
No. samples examined..		18	38	27	38	38						

In estimating the amount of stems in an unknown sample, its nitrogen and phosphorus pentoxid contents are compared with the average values for these determinations in samples of flowers and stems.[1]

The formula for making the calculations is as follows:

$$X = \frac{100\ (a-c)}{a-b}$$

in which X = percentage of stems in sample.

a = average percentage of nitrogen or P_2O_5 in flowers.

b = average percentage of nitrogen or P_2O_5 content of stems.

c = nitrogen or P_2O_5 content of sample.

The value of a differs as to whether the mixture is made up with "open" flowers and stems or with "closed" flowers and stems.

In the case of "open" flowers and stems:

(1) Based on nitrogen values—

$a = 1.267$

$b = 0.765$

$$X = \frac{100\ (1.267-c)}{1.267-0.765} = 200\ (1.267-c)$$

(2) Based on P_2O_5—

$a = 0.532$

$b = 0.234$

$$X = \frac{100\ (0.532-c)}{0.532-0.234} = 336\ (0.532-c) = \frac{100\ \ (0.532-c)}{3}$$

In mixtures of closed flowers and stems:

(1) Based on nitrogen values—

$a = 1.784$

$b = 0.765$

$$X = \frac{100\ (1.784-c)}{1.784-0.765} = 98\ (1.784-c)$$

(2) Based on P_2O_5—

$a = 0.691$

$b = 0.234$

$$X = \frac{100\ (0.691-c)}{0.691-0.234} = 220\ (0.691-c)$$

In connection with other observations, the crude fiber determination is of value in indicating whether open or closed flowers have been used in the mixture. In most cases these mixtures are made up from "open" flowers, which are cheaper than "closed," and stems, though sometimes "closed" flowers are employed. The question then arises, how can the analyst tell whether "open" or "closed" flowers have been used and which values to apply in the formula.

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[1] In obtaining these averages the results of analyses of all cleaned and uncleaned flowers and stems, and also of commercial samples of flowers (with a small part of the stem left attached when harvested), were included. Theoretically the averages should have been based either on cleaned flowers, without attached stems, and on cleaned stems, or on commercial flowers as marketed (with the dirt and short stems still present), and on commercial stems containing the normal percentage of foreign matter. However, the amount of stems and foreign matter in commercial flowers and the amount of foreign matter in stems are so small that the error introduced in this way is negligible.

This may be determined in the following ways:

1. Examination by a microscopist will show whether "open" or "closed" flowers have been used. The presence of a large amount of pollen and the absence of fruit tissues indicate "closed" flowers; and, conversely, the absence of much pollen and the presence of a large amount of fruit tissues indicate "open" flowers. These tissues are very characteristic and can not be mistaken (Pl. IV).

2. Mixtures of flowers and stems are made up on the basis of lowest cost. By following the market prices on "closed" and "open" flowers and stems, the analyst can usually tell which has been used in preparing a mixture of flowers and stems.

3. From the intensity of the green color of the ether extract, after a little experience, the amount of stems present can be told roughly.

4. The crude fiber determination, taken in connection with the intensity of the green color of the ether extract, general appearance of the powder, and odor, serves as a good indicator as to whether or not the mixture is composed of "open" flowers and stems or "closed" flowers and stems.

By a combination of all of these tests, but more particularly by microscopical examination, it is possible to tell whether "closed" or "open" flowers have been used in a mixture, and, by the use of the formula, to determine the approximate percentage amount of flowers and stems present.

In Table 37 are given the nitrogen and phosphorus pentoxid contents of 10 known mixtures of open flowers with stems, and the amount of stems calculated from each of these values, using the formulas just given.

Table 37.—*Nitrogen and phosphorus pentoxid content of known mixtures of open flowers and stems and amount of stems present.*

Sample No.	Stems.	Nitrogen, N.	P_2O_5.	Stems calculated from—		Mean.	Error.
				Nitrogen, N.	P_2O_5.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	0	1.280	0.530	3	1	2	+ 2
2	0	1.235	.523	6	3	5	+ 5
3	0	1.250	.510	3	7	5	+ 5
4	10	1.185	.459	16	24	20	+10
5	10	1.170	.482	19	17	18	+ 8
6	20	1.140	.411	25	40	33	+13
7	20	1.170	.447	19	28	24	+ 4
8	60	1.035	.275	46	86	66	+ 6
9	60	.919	.300	70	77	74	+14
10	80	.947	.206	64	100	82	+ 2
Minimum error							2
Maximum error							14
Average error							6.9

Tables 38 and 39 give the results of the analysis of commercial insect powders. Those reported in Table 38 are on the samples unadulterated with stems, foreign plant material, or coloring matter, while those in Table 39 are on samples adulterated with ground Pyrethrum stems, sand, chromates, or other materials.

TABLE 38.—*Analysis of commercial insect powders unadulterated with Pyrethrum stems, foreign plant material, or coloring matter.*

Sample No.	Made in—	Nitrogen, N.	Ash.	Ash insoluble in HCl.
		Per ct.	*Per ct.*	*Per ct.*
11157	United States	1.64	8.92	0.84
11292	do	1.29	6.73	.22
12033	do	1.55	8.07	.98
12034	do	1.56	9.01	1.33
12212	England	1.52	7.67	.43
12217	United States	1.56	7.67	.95
12273	do	1.65	9.93	....
12613	England	1.63	7.54	.17
12654	United States	1.26	7.22	.66
12657	do	1.35	8.57	2.22[1]
12660	do	1.25	6.49	.24
12920	do	1.54	7.09	.33
13202	do	1.75	7.08	.75
13603	do	1.40	7.70	.99
13649	do	1.53	7.25	.89
13695	Austria	1.26	6.29	.33
13768[2]	United States	1.60	7.37	1.47
13860	do	1.61	7.58	.95
13921	do	1.54	7.15	.74
13923	do	1.57	6.93	.68
13985	do	1.23	6.05	.27
14197	do	1.14	6.11	.39
14370	do	1.35	6.90	.64
14381	do	1.72	7.03	.13
14445	do	1.26	5.77	.26
14523	do	1.24	8.14	.97
14730	do	1.66	7.57	.75
14992[2]	do	1.62	7.12	1.00
15153	Austria	1.76	7.83	.36
15224	Italy	1.49	7.00	.31
15272	United States	1.41	8.48	1.69
15366	do	1.21	7.09	.96
15730	Austria	1.29	6.23	.39
15850	United States	1.54	7.02	.33
16018	Japan	1.66	7.19	.67
16019	do	1.72	6.91	.49
16499	England	1.54	8.34	2.00[1]
16546	United States	1.48	8.09	1.01
16611	do	1.30	7.75	1.64
16796	Japan	1.71	6.69	.44
17459	do	1.66	6.39	.46
17619	United States	1.82	8.64	.15
17624	do	1.64	7.74	.93
17671	Germany	1.64	7.43	.09
17672	do	1.53	7.49	.09
18022	England	1.82	8.23	1.26
18149	United States	1.23	7.00	.12
18151	do	1.80	8.72	.29
18156	do	1.46	8.20	.83
18159	do	1.95	8.36	.36
18383	do	1.27	7.78	1.09
18622	do	1.48	6.91	.56
18719	do	1.52	7.04	.31
19187	Japan	1.72	7.38	.91
19273	England	1.61	7.83	.95
19283	Australia	1.28	6.54	.18
19320	United States	1.24	6.74	.66
19643	do	1.20	7.73	2.42[1]
19660	do	1.34	6.70	.34
19661	do	1.56	7.46	.43
19671	do	1.56	7.42	.81
19825	do	1.15	7.25	1.59
19833	do	1.28	6.99	.78
20097	do	1.44	7.67	1.22
20224	do	1.24	6.49	.51
20225	United States	1.08	7.76	2.42
20226	do	1.13	6.03	.33
20250	do	1.15	6.15	.27
20373	do	1.26	7.48	1.15
20456[2]	do	1.30	5.47	.69
20462	do	1.20	6.79	.80
20472	do	1.26	7.11	.62
20658	do	1.18	6.80	.70
20771	do	1.21	6.98	.70
21043	do	1.60	7.29	1.51
21148	do	1.22	6.73	.56
21371	Japan	1.78	7.09	.65
21941	United States	1.73	8.06	1.02
21969	do	1.31	6.54	.28
22180	Japan	1.66	7.49	1.71
22637	United States	1.28	6.69	.53
22641	do	1.45	8.08	.97
22701	do	1.73	8.10	1.19
22756	"Imported"	1.33	10.00	2.47[1]
22764	United States	1.69	7.35	.84
22804	do	1.47	10.09	1.49
22894	do	1.41	8.71	1.24
22895	do	1.66	9.07	.51
22968	do	1.30	6.81	.51
22972	do	1.67	8.90	.59
23071	do	1.33	8.04	1.24
23246	do	1.65	8.47	.34
23330	do	1.28	7.09	.67
23353	do	1.64	7.03	.78
23403	do	1.42	7.36	.76
23491	do	1.83	7.26	.64
23561	do	2.01	7.05	.70
23647	do	1.85	7.10	.77
23648	do	1.74	6.89	1.02
23655	do	1.65	6.53	.58
23727	do	1.48	8.19	1.11
23918	Japan	1.43	9.67	4.32
23990	do	1.86	7.47	.91
23949	United States	1.77	6.85	.90
23969	do	1.70	7.06	.70
24077	do	1.89	6.56	.45
24083	do	1.84	7.19	.77
24112	do	1.88	7.61	1.21
24123	do	1.76	7.40	1.00
24124	do	1.77	7.47	.94
24125	do	1.74	7.47	.92
24126	do	1.81	7.53	1.03
24127	do	1.65	6.84	.82
24189	Japan	1.80	6.90	.55
24276	United States	1.81	7.75	1.07
24277	do	1.73	7.48	1.04
24278	do	1.85	8.23	1.45
24279	do	1.77	7.71	1.09
24280	do	1.68	7.50	.99
24281	do	1.73	7.72	1.31
24282	do	1.79	8.58	1.82
24283	do	1.70	7.42	1.06
24284	do	1.79	7.37	.86
24285	do	1.76	6.97	.64
24286	do	1.87	8.15	1.33
24287	do	1.80	8.19	1.64
24301	do	1.80	7.23	.68
24303	do	1.74	8.76	1.90
24307	do	1.35	7.98	.61
24314	do	1.67	7.69	.51

[1] Contains sand.

[2] *C. cinerariæfolium* grown in California.

TABLE 38.—*Analysis of commercial insect powders unadulterated with Pyrethrum stems, foreign plant material, or coloring matter*—Continued.

Sample No.	Made in—	Nitrogen, N.	Ash.	Ash insoluble in HCl.
	United States....	*Per ct.*	*Per ct.*	*Per ct.*
24315	.....do............	1.68	7.71	0.53
24316	.....do............	1.70	7.70	.51
24317	.....do............	1.59	7.58	.62
24318	.....do............	1.55	7.57	.64
24319	.....do............	1.59	7.42	.62
24320	.....do............	1.65	7.66	.54
24321	.....do............	1.54	7.46	.64
24322	.....do............	1.63	7.92	1.11
24323	.....do............	1.59	7.88	1.52
24324	.....do............	1.49	7.38	.98
24325	.....do............	1.51	8.06	1.67
24326	.....do............	1.43	8.04	1.55
24327	.....do............	1.43	7.81	1.46
24328	.....do............	1.45	7.83	1.60
24329	.....do............	1.51	7.65	1.53
24330	.....do............	1.45	8.02	1.78
24331	.....do............	1.49	7.93	1.87
24332	.....do............	1.59	9.26	3.61[1]
24333	.....do............	1.52	7.17	1.05
24334	.....do............	1.65	7.62	1.37
24335	.....do............	1.62	7.89	1.41
24336	.....do............	1.43	7.57	1.77
24337	.....do............	1.48	7.68	1.74
24338	.....do............	1.45	6.67	.91
24339	.....do............	1.54	7.84	1.29
24340	.....do............	1.48	7.87	1.90
24341	.....do............	1.39	7.34	1.73
24342	.....do............	1.41	7.91	2.15
24343	.....do............	1.51	7.78	1.53
24344	.....do............	1.45	7.62	1.96
24345	.....do............	1.79	7.89	.58
24346	.....do............	1.73	7.59	.46
24347	.....do............	1.63	7.03	.40
24348	.....do............	1.67	7.24	.35
24349	.....do............	1.71	7.32	.33
24350	.....do............	1.62	7.41	.99
24351	United States....	1.62	7.46	0.70
24352	.....do............	1.63	7.41	.87
24353	.....do............	1.65	8.01	1.04
24354	.....do............	1.56	7.53	.91
24355	.....do............	1.70	7.71	.43
24356	.....do............	1.65	7.84	.73
24426	.....do............	1.51	7.46	1.49
24437	.....do............	1.73	6.87	.69
24643	.....do............	1.76	7.44	1.04
24644	.....do............	1.76	7.57	1.15
24645	.....do............	1.79	7.81	1.29
24646	.....do............	1.77	7.43	1.05
24647	.....do............	1.77	7.64	1.27
24648	.....do............	1.73	7.56	1.14
24649	.....do............	1.77	7.55	1.13
24650	.....do............	1.77	7.42	1.12
24651	.....do............	1.80	7.93	1.46
24652	.....do............	1.80	7.59	1.10
24653	.....do............	1.52	6.59	.81
24708	Europe...........	1.34	7.77	.72
24736[2]	United States....	1.59	7.35	1.08
24779	Europe...........	1.20	7.07	1.27
24798	United States....	1.56	7.80	1.22
24812	Japan............	1.59	8.63	2.99[1]
24820[2]	....do............	1.66	6.86	.66
25062	United States....	1.68	7.54	1.18
25069	.....do............	1.26	6.75	.20
25070	.....do............	1.68	8.01	.29
26188[2]	....do............	1.32	5.53	.44
33035[2]	....do............	1.56	6.46	.68
	Minimum..........	1.08	5.47	.09
	Maximum..........	2.01	10.09	4.32
	Average...........	1.558	7.52	.96
	No. samples examined.	193	196	195

[1] Contains sand.

[2] *C. cinerariæfolium* grown in California.

TABLE 39.—*Analysis of adulterated commercial insect powders.*

Sample No.	Made in—	Nitrogen, N.	Ash.	Ash insoluble in HCl.	Color of ether extract.	Adulterants.
		Per ct.	*Per ct.*	*Per ct.*		
11301	United States..	0.895	10.26	3.32	Strong green..........	Stems and sand.
11819	.....do.........	1.155	7.72	1.28	.....do..............	Stems.
11831	.....do.........	.884	6.28	.69	.....do..............	Do.
12031	.....do.........	.891	6.76	1.83	.....do..............	Stems and sand.
12073	.....do.........	1.080	7.17	1.88	.....do..............	Do.
12303	.....do.........	1 060	9.86	3.56	Dirty pale yellow.....	Do.
12466	.....do.........	1.122	12.70	5.50	Green................	Do.
12658	.....do.........	1.135	7.77	1.90	...do................	Do.
13238	.....do.........	1.120	7.06	.57	.....do..............	Stems.
13286	.....do.........	.910	5.43	.07	.....do..............	Do.
13287	.....do.........	1.090	7.81	.16	.....do..............	Do.
13311	.....do.........	1.120	6.24	.57	Greenish.............	Do.
13823	Italy...........	1.370	8.71	....	Slightly greenish yellow.	Lead chromate (2.82 per cent).
13824	Austria.........	.990	7.31	....	Strong green..........	Stems and 2.27 per cent lead chromate.
13857	United States..	1.180	7.60	.86	Greenish yellow.......	Stems and unidentified bark.
13925	.....do.........	1.140	9.78	2.10	.....do..............	Stems and sand.
14039	.....do.........	.950	6.37	.69	Strong green..........	Stems.
14105	.....do.........	1.145	9.60	2.26	.....do..............	Stems and sand.
14362	.....do.........	.947	6.77	1.54	.....do..............	Stems.
14550	.....do.........	.919	6.31	.67	.....do..............	Do.
14854	.....do.........	1.120	6.12	.55	Greenish yellow.......	Do.
15393	Austria.........	1.210	7.30	.55	Green................	Stems and 1.48 per cent lead chromate.
16920	.....do.........	.820	23.43	....	.....do..............	Stems, calcium carbonate, and 2.07 per cent barium chromate.

TABLE 39.—*Analysis of adulterated commercial insect powders*—Continued.

Sample No.	Made in—	Nitrogen, N.	Ash.	Ash insoluble in HCl.	Color of ether extract.	Adulterants.
		Per ct.	*Per ct.*	*Per ct.*		
17384	United States	0.954	7.14	0.85	Green	All stems.
17420	do	.856	5.70	.90	do	Do.
17998	do	.947	5.66	.56	do	Stems.
18153	do	.849	7.62	1.14	do	All stems.
19145	do	.807	6.36	.61	Strong green	Stems.
19846	do	1.030	6.69	1.42	do	Do.
20765	do	1.185	7.18	1.13	Greenish yellow	Do.
20786	do	.887	6.06	.37	Strong green	Do.
20787	do	1.060	7.19	.74	Green	Do.
20793	do	.954	6.16	.61	do	Do.
20940	do	.772	4.96	.59	Strong green	Do.
21115	do	1.145	10.12	4.31	Greenish yellow	Stems and sand.
22215	do	1.015	6.09	.40	Dirty green	Potassium chromate and stems.
23161	do	.786	5.27	.66	Strong green	All stems.
23369	do	1.040	6.57	.80	Green	Stems.
23479	do	1.165	6.75	.83	do	Do.
23547	do	1.090	7.05	.70	do	Do.
24030	do	1.050	8.68	3.18	do	Stems and sand.
24768	do	1.120	7.00	.76	do	Stems.
24769	do	.898	6.38	.69	Strong green	Do.
25046	do	1.170	6.10	.82	Green	Do.

TABLE 40.—*Analysis of commercial powders containing stems, amounts declared, made from "open" flowers and stems.*

Sample No.	Nitrogen, N.	P_2O_5.	Stems stated to be present.	Stems calculated from— Nitrogen, N.	Stems calculated from— P_2O_5.	Mean.	Error.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
12031	0.891	0.289	75	75	81	78	+3
12073	1.080	.402	50	37	43	40	−10
12658	1.135	.385	50	26	49	38	−12
14039	.950		50	63			+13
14362	.947	.284	75	64	83	74	−1
19846	1.030		50	47			−3
20786	.887	.316	70	76	72	74	+4
20787	1.060	.390	40	41	47	44	+4
20793	.954		50	62		62	+12
23161	.786		100	96			−4
23369	1.040		50	45			−5
23547	1.090		50	35			−15
24030	1.050		50	43			−7
Minimum error							1
Maximum error							15
Average error							7

From Table 40 it is evident that the amount of stems in commercial insect powder determined by the proposed method of calculation from the values for nitrogen and phosphorus pentoxid agrees within an average of less than 10 per cent of the amount declared to be present.

In some cases the ash and acid-insoluble ash contents in insect powders have been found to be higher than they should be, based on those determinations made on samples of known purity and on samples of flowers and stems. Some jobbers have claimed that the high ash content of their product was due to the addition by the manufacturer of siliceous material during the grinding or to the introduction of mineral matter during the grinding as a result of abrasion from the mill. In the case of stone mills there would be some wearing of the stones and a small amount of material would be introduced into the powder in this way. It can readily be seen, however, that if this were sufficient to increase the ash content appreciably, say, 1 per cent, there would soon be nothing left of the mill.

In order to determine whether there was any marked difference in the composition of the powder from that of the flowers from which it was made, a number of samples of "closed" Japanese flowers were collected immediately before entering the mill and samples of the ground product as it came from the mill. Owing to the great capacity of the milling and sieving machinery, the powder from any particular sample of flowers could not be identified, but when collected over a period of a working day an average of all samples collected should be representative of the material. In Table 41 are given the analyses of these samples, which represent a run of about 60 bales (25,000 pounds) of "closed" Japanese flowers. Table 42 contains the results of analyses of Japanese stems before and after grinding.

TABLE 41.—*Analysis of Japanese "closed" flowers before and after grinding.*

Flowers.			Powder.		
Nitrogen, N.	Ash.	Ash insoluble in HCl.	Nitrogen, N.	Ash.	Ash insoluble in HCl.
Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1.96	6.75	0.28	1.735	6.77	0.53
1.66	6.95	.32	1.705	7.15	.74
1.82	6.85	.65	1.89	6.56	.45
1.78	6.67	.29	1.84	7.19	.77
1.72	6.92	.68	1.88	7.61	1.21
1.76	7.09	.79	1.76	7.40	1.00
1.77	7.01	.74	1.77	7.47	.94
1.79	6.88	.47	1.74	7.47	.92
1.80	7.15	.82	1.81	7.53	1.03
1.94	7.43	.97	1.65	6.84	.82
1.76	7.70	1.21	1.81	7.75	1.07
1.73	7.19	.77	1.73	7.48	1.04
1.82	7.39	.97	1.85	8.23	1.45
1.76	6.96	.60	1.77	7.71	1.09
1.81	7.40	.98	1.68	7.50	.99
1.81	7.26	.81	1.73	7.72	1.31
1.88	7.33	.79	1.79	8.58	1.82
1.84	8.58	2.03	1.70	7.42	1.06
1.84	7.72	1.11	1.79	7.37	.86
1.91	7.46	.89	1.76	8.97	.64
1.87	7.50	.94	1.87	8.15	1.33
1.82	7.63	1.05	1.80	8.19	1.64
1.81	7.84	1.22	1.76	7.44	1.04
1.80	7.72	1.34	1.76	7.57	1.15
1.90	8.22	1.83	1.79	7.81	1.29
1.70	7.28	1.04	1.77	7.43	1.05
1.93	7.26	1.07	1.77	7.64	1.27
1.90	8.31	1.77	1.73	7.56	1.14
1.91	7.82	1.36	1.77	7.55	1.13
1.98	7.68	1.15	1.77	7.42	1.12
1.87	7.59	1.05	1.80	7.93	1.46
1.84	7.37	.99	1.80	7.59	1.10
1.91	7.12	.76	1.52	6.59	.81
1.77	7.22	.94			
[1] 1.83	[1] 7.42	[1] 1.00	[1] 1.77	[1] 7.54	[1] 1.10

[1] Average.

TABLE 42.—*Analysis of Japanese Pyrethrum stems,*[1] *before and after grinding.*

Unground stems.			Powdered stems.		
Nitrogen, N.	Ash.	Ash insol. in HCl.	Nitrogen, N.	Ash.	Ash insol. in HCl.
Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
0.982	5.03	1.10	0.706	4.29	0.85
.814	5.58	1.50	.765	4.54	1.02
.854	5.07	.79	1.015	6.26	1.94
.948	5.63	1.45	.877	5.50	1.57
.884	4.81	.90	.891	5.75	1.66
			.842	5.03	1.15
			.954	5.86	1.54
			.891	5.71	1.69
			.912	5.71	1.72
			.926	5.88	1.80
			.758	4.75	1.15
			.961	6.03	1.84
			.940	5.81	1.81
			.891	5.67	1.67
			.863	5.07	1.28
			.870	5.57	1.55
.916[2]	5.22[2]	1.15[2]	.879[2]	5.46[2]	1.52[2]

[1] These stems originally contained much "dirt" which was removed by sieving, 16 per cent being thus thrown away. The figures reported are on the stems after removal of all dirt. The discarded sievings analyzed:

Nitrogen, N.	Ash.	Ash insoluble in HCl.
Per cent.	*Per cent.*	*Per cent.*
1.93	21.62	13.99
1.93	23.23	15.67
1.82	23.64	16.19

[2] Average.

The average results for nitrogen, total ash, and ash insoluble in hydrochloric acid in the flowers before and after grinding agree closely, showing that no appreciable change in composition is brought about by the process of grinding.

In the case of stems the figures for total ash and acid-insoluble ash are a little higher in the ground product. This is no doubt due in part to the sampling, as it is difficult, in the case of the unground stems, to obtain a uniform sample, owing to the nature of the material and to the way in which it is packed.

Practically all the insect flowers imported into this country are the *Chrysanthemum cinerariæfolium,* but after the beginning of the recent European war a few shipments of flowers of *Chrysanthemum roseum* were received from Russia, through Marseilles or Italian ports. The results of analysis of these samples are given in Table 43. A comparison of these results with the corresponding figures for the various grades of flowers and stems of *C. cinerariæfolium* shows that the ash and nitrogen contents of *C. roseum* are higher and the ether extract and pentosans are lower than those of either the flowers or stems of the *C. cinerariæfolium.* The values for crude fiber and phosphorus pentoxid of *C. roseum* correspond closely to those of the closed flowers of *C. cinerariæfolium.* The powder prepared from the flowers of *C. roseum* is much darker and has a different odor than the ordinary insect powder. The odor of an insect powder and a microscopical examination should serve as a means to determine whether or not the product has been prepared from *C. roseum* or *C. cinerariæfolium.*

TABLE 43.—*Analysis of insect flowers (Chrysanthemum roseum).*

Sample No.	Nitrogen, N.	P_2O_5.	Ether extract.	Pentosans.	Crude fiber.	Ash.	Ash insoluble in HCl.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17879	2.08					8.75	0.60
18011	2.08					8.45	.35
20487	2.26	0.714	2.83	13.78	20.44	11.09	1.11
21737	1.95	.691	2.74	13.21	20.04	10.89	1.45
22076	2.04	.738	2.73	13.42	19.31	11.90	1.51
22295	1.97					12.62	3.42
22575	2.08	.640			18.46	9.15	.45
22693	2.00	.581			17.80	9.88	1.26
Minimum	1.95	.691	2.73	13.21	19.31	8.45	.35
Maximum	2.26	.738	2.83	13.78	20.44	12.62	3.42
Average	2.08	.714	2.77	13.47	19.93	10.34	1.27

Samples of *Chrysanthemum leucanthemum* (generally called "field daisy" or "oxeye daisy" in this country), which have been largely used in the past, and to some extent at the present time,[1] as an adulterant of insect powder, have been analyzed in the Insecticide and Fungicide Laboratory (Table 44).

TABLE 44.—*Analysis of Chrysanthemum leucanthemum.*

Sample No.	Description.	Nitrogen, N.	Ash.	Ash insoluble in HCl.	P_2O_5.	Ether extract.	Pentosans.	Crude fiber.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
[1] 14933	Flowers only	1.82	10.02	0.92	0.684	3.18	14.34	20.14
[2] 23020	do	2.23	10.45	.15				
23020	Stems only	1.45	10.38	.15				

[1] Sent in as "false" insect flowers.

[2] Collected near Markham, Va.

ACTIVE PRINCIPLE OF INSECT POWDER.

PREVIOUS INVESTIGATIONS.

The earliest recorded investigation on the active insecticidal constituents of insect powder is that of Ragazzini cited by de Visiani (67) in 1854. The powder prepared from the *Chrysanthemum cinerariæfolium* was used by Ragazzini in his experiments. His conclusion was that the narcotic action of the powder was due not to any single substance but rather to a mixture of substances.

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[1] U. S. Dept. Agr. Bull. 795.

Hanamann (114), in 1863, referred to previous work by Heller and Kletzinsky, stating that they found genuine Persian insect powder to contain no narcotic or alkaloidal plant poisons or poisonous mineral substances, but only ethereal oil and santonin, as the active insecticidal constituents. From his own experiments Hanamann concluded that Pyrethrum flowers contain no poisonous acting alkaloid or santonin, but mostly indifferent substances, and that only the ethereal oil in concentrated form can have any harmful effect. He stated that genuine insect powder can not have the slightest harmful action on the human organism.

Rother (234), in 1876, recorded the results of some tests made upon Pyrethrum, but the species he used is not indicated. The absence of alkaloids is proven, and the active principle is stated to be a glucoside, called *persicin*, which can be split up into glucose and an inert body called *persiretin*. He also isolated a yellowish, bitter resin, designated as *persicein*. Later, Rother (235) states that *persicin* is not a glucoside and that the glucose reaction is due to glucose or a gum preexisting in the powder. Thus the matter is left in a state of confusion.

Jousset de Bellesme (63), in 1876, stated that the toxic principle of insect powder is entirely extracted by alcohol. He isolated the essential oil of Pyrethrum, and proved its harmlessness on insects. As he expresses it, after having submitted Pyrethrum to the treatment proper to extract an alkaloid, he obtained a crystallized principle which enjoyed to a high degree the toxic properties of the plant. This account of the work of de Bellesme is simply an abstract of an address he made before the Biological Society of Paris. Statements are made, but no experimental proof is given.

Semenoff (253), in 1877, obtained flowers of Pyrethrum, presumably *Pyrethrum roseum* or *carneum*, from Caucasia, near the Turkish boundary. Dried at 25° C., the flowers were as active against insects as commercial insect powder. An essential oil was obtained by steam distillation, but proved to be inactive. By distillation in an alkaline solution a very small amount of an alkaloid was obtained. By macerating 1 pound of the flowers with 5 pounds of ether for 5 days, and evaporating the extract, a mixture of resin, oil, wax, and acids was obtained, which on steam distillation yielded an ethereal oil that killed insects.

Hager (111), in 1878, reported that the insecticidal activity of the flowers of *Pyrethrum carneum* and *roseum* was due to two substances. One was a body similar to trimethylamin which was found in the flowers combined with an acid; the other was a resin found in the pollen grains. Hager obtained some of the first substance in combination with hydrochloric acid, added to it some potassium hydroxid solution, and noticed that flies held over the mixture exhibited convulsive movements. The resin when dusted on insects acted very energetically. Solutions of the powder made with water or with dilute alcohol were found to be entirely inactive.

Dal Sie (60), in 1879, claimed to have proven the presence of a free, easily volatilized acid which was found in the ethereal, alcoholic, or aqueous extracts of the powder. From the ether extract of the flowers he obtained not only a crystallizable acid, but also an aromatic smelling acid of oily consistency at ordinary temperature. From the alcoholic extract he obtained a resinous matter resembling a glucoside, probably the same as that found by Rother, since under the influence of dilute sulphuric acid it split up into sugar and another product. According to Dal Sie, since the fumes which result from the incomplete combustion of insect powder exhibit the toxicity of the original powder, the toxic principle must be volatile without decomposition, and the free volatile acid is, therefore, the most active constituent of Pyrethrum.

Oscar Textor (272), 1881, as the result of his tests, stated that "the active principle of Persian insect powder is, in nature, a soft resin." He pulverized (80-mesh) 1½ ounces of whole flowers (species not indicated), and percolated the powder with benzine for 6 hours, using 6 fluid ounces. The benzine solution was evaporated, water added, and again evaporated to remove any volatile oil. The residue was treated with dilute acid and filtered. No alkaloid could be detected in the filtrate by phosphomolybdic acid, Mayer's reagent, or by a solution of iodin in potassium iodid. The benzine extract, the benzine extract in alcohol precipitated by acid, and the benzine extract in caustic potash and precipitated by acid, were all poisonous to flies. The benzine extract in alcohol was acid to litmus. A test for essential oil was made by allowing the powder to stand in dilute salt solution for 24 hours and then distilling, but none was obtained.

Hirschsohn (133), in 1890, found that alcohol, ether, chloroform, or benzine would dissolve the active principle of insect powder. The extract obtained with these solvents, when added to an inactive powder, e. g., powdered chamomile, produced a powder as active as the original insect powder before extraction. From the work of Hirschsohn, the active principle would appear to be nonvolatile, as he found samples of powder which had stood for 5 years in paper boxes still as active as fresh powder. Heated at 120°, insect powder lost its odor, but was as active as ever against flies. To see if the active principle was acid in nature, he treated powder with alcoholic ammonia, also with alcoholic potash, but after drying in the air the powder was as active as ever. Placed for 24 hours in water, the water became acid, but the powder after drying was still active.

Gillette (96), in 1889, arrived at the same conclusions as to the absence of toxic substances in the volatile oil of Pyrethrum. He made practical tests upon insects, operating as follows:

> Two or 3 grams of the powder were first put in a test tube and the dust allowed to settle for a few minutes. Then a loose cotton plug was pushed halfway down in each, upon which were placed the insects, and the tubes were then tightly corked. Dipterons, ichneumons, chalcids, cynipids, and aphids were subjected to this treatment, and allowed to remain for different lengths of time, varying from 1 or 2 to 40 hours, without showing any signs of being affected by the volatile oil.

To see if the toxic principle of Pyrethrum would come off at a higher temperature, Gillette made further tests:

> Two cynipids were then similarly inclosed in a tube with fresh powder and the lower end of the tube was held for 10 minutes in a dish of boiling water, the upper end of the tube being kept cool with a wet cloth. The insects were allowed to remain for a few minutes after the boiling, but showed no signs of being affected by the treatment.
>
> Another tube was then prepared in which were confined other cynipids in a manner similar to the preceding, and the tube was held over the flame of an alcohol lamp and constantly shaken until the powder was entirely browned, care being taken not to burn it. The insects were unhurt by this treatment.
>
> Then a quantity of powder was put in a tube and held in the flame of a lamp until the tube was filled with fumes. These fumes were poured over into another tube in which was an ichneumon, on which they took immediate effect and death ensued in a very few minutes.
>
> Next, three ichneumons were enclosed in separate tubes. One was shaken up with a small amount of fresh Pyrethrum powder, one with a small amount of the browned powder spoken of in the second preceding experiment, and one in a small amount of the partially burned powder spoken of in the preceding experiment. In each case the insect was killed, the fresh and the browned articles acting alike, and the partially burned powder acting somewhat slower.
>
> Three grams of the powder were then put in about 90 cc. of water in a retort and boiled for one-half hour, the vapor being caught and condensed in a receiver. Soon after boiling began a slight odor was noticed escaping about the mouth of the receiver which the neck of the retort did not quite fill. A cynipid was entangled in a bit of cotton and crowded into the opening, where it remained for 12 minutes without being affected.
>
> About one-half of the liquid was sent over in the above experiment, and the distillate was clear, colorless, and almost tasteless and odorless, there being a slight taste resembling steeped hay. The distillate and the residue were used to compare their insecticidal properties with one another and with fresh powder extracted in cold water for 24 hours. The results of these experiments were that the distillate used pure killed but a very small percentage of the lice treated and that the residue was as efficient as the same amount of powder extracted in cold water.

Gillette found that ether extracted all the insecticidal principle from Pyrethrum, as the extracted powder when dusted upon insects had no effect. The greater part of the ether extract would dissolve readily in water, and this water solution affected insects exactly as if they had been treated with Pyrethrum.

Zuco (296), in 1889, made an ethereal extract of the flowers of *Chrysanthemum cinerariæfolium*. After repeated treatment of this with aqueous and alcoholic potash a substance was left which formed yellow crystals and had a melting point of 70° to 100°. After repeated recrystallization from cold ether a paraffin, $C_{17}H_{36}$, of melting point 64°, was obtained. This dissolved freely in ether, benzene, chloroform, and moderately hot alcohol, but was almost insoluble in cold alcohol. The portion remaining in cold ether was recrystallized until the melting point was above 150°. Pure cholesterin was prepared from either the acetyl or benzoyl derivative of this substance by the action of alcoholic potash. The cholesterin thus obtained had a melting point of 183°; the melting point of its acetyl derivative was 223°, and that of the benzoyl derivative, 246°. It dissolved freely in ether, benzene, and chloroform, sparingly in hot alcohol, and gave all the reactions for cholesterin.

In 1890, Zuco (297, 298) obtained a glucoside and also an alkaloid from the flowers of *Chrysanthemum cinerariæfolium*. He described the glucoside as crystalline, but not enough was obtained for proper investigation. Later, Zuco (299) described the method he used in obtaining the alkaloid, called chrysanthemine, from Pyrethrum flowers. Ten kilograms of flowers were boiled in distilled water for 2 or 3 hours, filtered through cloth, the residue pressed and treated again in the same manner. The extracts were evaporated down to 30 liters, treated with neutral lead acetate and basic lead acetate, neutralized with soda, filtered, and the excess of lead removed by passing hydrogen sulphid. After filtration, the liquid was concentrated to about 2 liters, boiled for some time with dilute sulphuric acid, filtered again, and boiled until no more resinous matters were formed. The liquid was then decolorized with animal black, and an excess of the double iodid of potassium and bismuth added, which precipitated a heavy bright red crystalline powder. From this the alkaloid was obtained. According to Zuco this is a colorless sirup, soluble in water and in alkalis, soluble in ethyl and methyl alcohol, but not in ether, chloroform, or benzene. The base is described as being optically inactive and physiologically innocuous. The work of Zuco thus shows that the active insecticidal agent of Pyrethrum flowers is not alkaloidal in nature.

Eymard (77), in 1890, distilled a mixture of insect powder with 3 parts of water. The distillate was slightly opaline, held in suspension a small quantity of "essence," and presented a strong and characteristic odor of Pyrethrum flowers. Tested upon ants and other insects, however, the distillate was found to have no effect, from which Eymard concludes that the essential oil is not the active insecticidal agent of insect powder.

An ether extract was made, deep yellow and strongly odorous. It gave up nothing to water, but was completely soluble in 95 per cent alcohol and in alkalis. From alkaline solution it was precipitated by acid. From 110 grams of insect powder Eymard obtained

5.60 grams ether extract. This was dissolved in alcohol and treated with silver nitrate, which precipitated the fatty acids as silver salts, while the silver resinates remained in solution. The ether extract was in this manner shown to consist of 3.80 grams fatty bodies and 1.80 grams resinous matter. Insects placed upon a piece of paper impregnated with this resinous matter manifested extreme agitation and died in about 5 minutes. After exhaustion with ether, the insect powder was successively extracted with 95 per cent alcohol, cold distilled water, and boiling distilled water, but no toxic substances were obtained. No alkaloids were detected. Eymard concludes that the toxic principle of Pyrethrum is found in the part soluble in ether, and more especially in the resin. However, it is his opinion that several factors unite in the rôle of insecticide, as he found that the isolated active principle worked less actively than the original powder.

Schlagdenhauffen and Reeb (245), in 1890, distilled 250 grams of the flowers of Pyrethrum in a current of steam, collecting 750 grams of distillate. After filtering through a wet filter, the distillate was extracted with ether, the ethereal solution separated, filtered, and evaporated at a temperature not exceeding 30°. A few drops of a green oil which was toxic to insects were thus obtained. No alkaloid was present in the oil. The aqueous part was acid, but had no injurious effect upon insects. The authors obtained an acid which was toxic to insects, by exhausting with alcohol acidulated with hydrochloric acid, drying, exhausting with ether, shaking the ethereal solution with ammoniacal water, evaporating to dryness, again taking up in water, and filtering. The filtrate contains the ammonium salt of the toxic acid. This acid was also obtained by extracting with alcohol, neutralizing exactly with a solution of potassium hydroxid, evaporating gently to dryness, taking up in water, filtering, and treating the filtrate with a solution of tartaric acid, and extracting the liberated acid with ether. This toxic acid the authors call pyrethrotoxic acid. Injected into guinea pigs, this acid produced its action in 2 perfectly distinct stages. In the first, an excitation was produced, being more or less pronounced according to the proportion of matter administered; in the second stage, on the contrary, a complete prostration was produced, accompanied always with paralysis of the lower extremities.

Thoms (275), 1890, extracted 10 kilograms of best "closed" Dalmatian flowers with 55° petroleum ether for 7 days. Evaporated *in vacuo*, he obtained 230 grams of a greenish-yellow extract which had the characteristic odor of insect powder. This extract contained many crystals and was of a waxy consistency. By solution in alcohol and again evaporating, a yellow wax, melting point, 54°, was obtained. By pouring the alcoholic solution into water and setting in the direct sunlight, a white wax, of melting point 56.5°, was obtained. After separation of the waxy bodies from the solution a sugar (dextrose) was shown to be present. Altogether, Thoms succeeded in isolating from insect powder: (1) An essential oil, (2) a volatile acid, (3) a wax, (4) a nonvolatile, potassium permanganate reducing, balsamlike acid, (5) chlorophyll, (6) colophonic acid, (7) tannic acid, (8) a body with alkaloidal properties, (9) a body with glucosidal properties, and (10) sugar. Thoms found the petroleum-ether extract and the essential oil to possess toxic properties, while the nonvolatile acid, the glucoside, and the other substances were harmless to insects.

De Boisse (64), 1895, claimed that the active principle of *Pyrethrum cinerariæfolium* is a yellow resin soluble in sulphuric ether, insoluble in water, very slightly soluble in alcohol, carbon disulphid, and fatty bodies. Alkalis decompose it rapidly. The flowering heads and leaves contain a good deal of this resin; the lower parts of the stems, very little. De Boisse gives no experimental proof for these statements.

Durrant (73), in 1897, stated: "The toxic properties of insect powder are due to (1) a volatile oil amounting to 0.5 per cent in picked specimens of closed flowers and much less in open flowers; (2) a soft acid resinous body which is the principal source of the toxic effect. It is found to the amount of 4.8 per cent in selected closed flowers, less than 4 per cent in half-open flowers, and still less in flowers that are fully open; the whole plant apart from the flowers contains mere traces of resin."

Gerard (93), 1898, stated that the active principle of Pyrethrum consists of two different substances: (1) An oleo-resin, and (2) an essential oil. These are found principally in the bracts and around the ovaries of the flowers, comparatively little being found in the corollas.

Sato (236, 237), as a result of work done in 1905-1907, reports the isolation of a light-yellow, odorless, transparent, sirupy resin from Pyrethrum flowers, which he calls pyretol. At first this is tasteless, but later has a benumbing effect. It is insoluble in water and dilute acids, and soluble in alcohol, ether, and petroleum ether. It is soluble in hot alkaline solutions, but when precipitated from such solutions by acids the resin becomes completely inactive.

Fujitani (89), in 1909, conducted an elaborate research on the flowers of *Chrysanthemum cinerariæfolium,* using flowers cultivated in the Provinces of Ki-i and Mikawa, Japan. The flowers were ground and the powder soaked for 1 week in 95 per cent alcohol at room temperature. The alcohol was distilled off, leaving an extract of a greenish-brown color and a characteristic odor of insect powder, and quite toxic to insects. The yield was about 10 per cent. The alcohol extract was shaken up with water until entirely free from water-soluble substances. The residue was then dissolved in ether, the part insoluble in ether being treated with potassium hydroxid solution, and this then shaken out with ether. The deep-green ethereal solution was freed of chlorophyll, etc., by shaking with 10 per cent caustic-potash solution until the dark green turned to a yellow brown and the alkaline solution was entirely colorless. The ether solution was then shaken out once with dilute sulphuric acid, then with water, and finally the ether distilled off. This left a clear, yellow-brown mass which gave a neutral reaction and had a sharp and bitter taste and the characteristic odor of insect powder. The yield of this material was 1.4 per cent of the original material. For further purification the substance was dissolved in a little ether mixed with a large amount of petroleum ether, filtered, warmed with animal charcoal, and again filtered, and the petroleum ether then evaporated. A yellow sirupy mass was left, which had only a feeble odor, and a taste bitter at first and then intensely sharp. It gave a neutral reaction, was soluble in alcohol, ether, etc., but was insoluble in water, acids, and alkalis. It contained no nitrogen. This substance, which seems to be an ester, Fujitani calls pyrethron, and it is, according to him, the active insecticidal principle of Pyrethrum. Pyrethron decomposes even on standing, yielding pyrethrol, which appears to have the formula $C_{21} H_{34} O$. Tested upon different animals, pyrethron showed an action similar to that of veratrine. Fish and insects were very susceptible but protozoa very tolerant. On warm-blooded animals it caused epileptiform convulsions, increased blood pressure, and increased breathing movements.

Reeb (214), 1909, criticized Fujitani's work, arguing that treatment of the alcoholic extract with such powerful reagents as 10 per cent solution of potassium hydroxid and sulphuric acid might change bodies dissolved in the alcohol. Therefore it is not certain that the final product obtained by Fujitani, although toxic, is the real active preexisting principle. Reeb extracted Dalmatian insect powder with petroleum ether (specific gravity, 0.670). The petrolic liquids were filtered and evaporated, leaving a soft residue which represented 3.50 per cent of the powder employed. This was treated with successive quantities of hot alcohol in the presence of a little animal charcoal. The alcoholic solutions were filtered and allowed to stand about a month, at the end of which time a resin (melting point, 125°) had deposited. This resin Reeb calls pyrethresine. From the alcoholic solution Reeb separates pyrethrotoxic acid by evaporating to dryness, taking up in acetone, adding barium carbonate, evaporating to dryness, taking up in water, decomposing with sulphuric acid, and shaking out with ether, which upon evaporation leaves the pyrethrotoxic acid. From this work, therefore, Reeb verifies the work of himself and Schlagdenhauffen. According to Reeb, the toxic principle of insect powder is an acid called pyrethrotoxic acid, which preexists in the free state in the flowers of Pyrethrum.

In 1912 Yoshimura and Trier (295) published the results of their work upon the closed flowers of *C. cinerariæfolium* in search of betains. From 1 kilogram of air-dried powder they obtained 0.2 gram cholin and 0.8 gram stachydrin, both calculated as hydrochlorids. They made no tests as to the insecticidal action of these substances, but they are probably inert.

Siedler (258), 1915, distilled 30 kilograms of half-closed flowers with dry steam, extracted the distillate with ether, and thus obtained a salvelike mass of strong characteristic odor. The yield was 20.212 grams, or 0.067 per cent of the original material. Spread on unglazed porcelain, all was absorbed but 0.789 gram. By fractional recrystallization from aqueous alcohol 2 bodies were obtained from this unabsorbed portion: (1) Fine needles, melting point, 54–56°; and (2) fine plates, melting point, 58–60°. Recrystallized from absolute alcohol this substance had a melting point of 62°. Elementary analysis of (1) showed it to correspond closely to the formula $C_{14}H_{30}$. Analysis of (2) showed a formula approximating palmitic acid. The material absorbed by the porous plate was extracted with ether, and this concentrated solution mixed with 2 parts ether and 1 part alcohol. By extraction with sodium bisulphite solution, 0.049 gram of material was obtained of an aromatic odor, but without effect upon insects. By extraction with 2 per cent potassium hydroxid solution, 3.156 grams of material were isolated. No test for phenol could be obtained. An acid of butyric odor was obtained, but it was inert toward insects. Other tests, such as distillation of the material under reduced pressure, are recorded by Siedler, but nothing possessing insecticidal action could be isolated.

Evidently, then, a number of investigations on the nature of the active insecticidal principle of Pyrethrum have been carried out, but the results are at great variance. Table 45 gives a brief summary of these investigations.

TABLE 45.—*Summary of investigations on active insecticidal principle of Pyrethrum.*

Year.	Investigator.	Bibliography reference.	Species of Pyrethrum used.	Active principle considered to be—
1854	Ragazzini (de Visiani)	67	*Cinerariæfolium*	A mixture of substances, nature not determined.
1863	Heller & Kletzinsky (Hanamann.)	114	*Roseum* (?)	An essential oil and santonin.
1863	Hanamann	114	do.	An essential oil, "persicin."
1876	Rother	234,235	(?)	
1876	De Bellesme	63	(?)	A "crystallized principle."
1877	Semenoff	253	*Roseum* (?)	An essential oil.
1878	Hager	111	*Roseum* and *Carneum* (?).	A resin and an amin.

TABLE 45.—*Summary of investigations on active insecticidal principle of Pyrethrum*—Continued.

Year.	Investigator.	Bibliography reference.	Species of Pyrethrum used.	Active principle considered to be—
1879	Dal Sie	60	(?)	A free volatile acid.
1881	Textor	272	(?)	A soft resin.
1889	Gillette	96	(?)	Soluble in ether.
1889-1894	Zuco	296, 297, 298, 299	*Cinerariæfolium*	Isolated a paraffin, a phytosterol, an alkaloid, and a glucoside, but all were inert.
1890	Hirschsohn	133	*Roseum* (?)	Not acid and not volatile.
1890	Eymard	77	(?)	Principally a resin.
1890	Schlagdenhauffen and Reeb.	245	*Cinerariæfolium*	"Pyrethrotoxic acid."
1890	Thoms	275	do	An essential oil.
1895	De Boisse	64	do	A resin.
1897	Durrant	73	do	A resin and volatile oil.
1898	Gerard	93	do	An oleoresin and volatile oil.
1905 1907	Sato	236, 237	do	A sirupy resin, "pyretol."
1909	Fujitani	89	do	An ester, "pyrethron."
1909	Reeb	214	do	"Pyrethrotoxic acid."
1912	Yoshimura and Trier	295	do	Cholin and stachydrin (inert).
1915	Siedler	258	do	Nothing definite.

EXPERIMENTAL WORK.

PRELIMINARY TESTS.

The coarsely powdered flowers, subjected to steam distillation, yielded 0.28 per cent of a fragrant oil. This had an odor somewhat like that of rosemary oil, together with a characteristic Pyrethrum odor, but the amount obtained was too small to permit a chemical examination. Tested against flies, this oil had only slight repelling properties, and did not show the characteristic effects of Pyrethrum powder.

A steam distillation of the flowers in the presence of sodium hydroxid yielded only 0.15 per cent of oil, which had a disagreeable odor. Careful tests for alkaloids in the distillate gave negative results. A steam distillation of the flowers in the presence of a little sulphuric acid yielded 0.16 per cent oil, which lacked the characteristic odor of Pyrethrum. Tested against flies, the oils from the alkaline and acid steam distillations had even less effect than that obtained in a straight steam distillation. From these distillation experiments it may be concluded that the substance, or substances, in Pyrethrum which cause its characteristic effect upon insects are not removed by steam distillation in neutral, alkaline, or acid solutions.

After being subjected to steam distillation in neutral solution, the flowers were dried and tested upon roaches, when they were found to be as active as before treatment. This shows that treatment with steam does not decompose the insecticidal principle.

To test the action of dilute acid and alkaline solutions upon insect flowers, 50 grams of the coarsely powdered material were treated with 500 cc. of solution for 24 hours, stirred occasionally, then filtered off, and dried at room temperature. The residual powder, after treatment with 1 per cent hydrochloric acid (HCl), 1 per cent acetic acid (CH_3COOH), 1 per cent ammonium hydroxid (NH_4OH), or distilled water, was apparently as active as ever (tested against roaches), but after extraction with 1 per cent potassium hydroxid (KOH) the powder was entirely inert. These tests show that the active principle is soluble in dilute KOH, or else is rendered inert by it, but is insoluble in, or unaffected by, water, dilute acids, or dilute ammonium hydroxid.

Heated at 107° C. for 17 days the powder took on a markedly reddish color. All characteristic odor disappeared after about 3 days' heating. At the end of the 17-day period the powder was tested upon roaches, and found to be entirely inert. Heated in a vacuum oven at the temperature of boiling water for 14 hours, the powder completely lost its characteristic odor, but was still active against roaches. This again indicates that the essential oil does not contain the characteristically acting insecticidal principle.

Different portions of the powder were dried over sulphuric acid and solid sodium hydroxid in desiccators *in vacuo* for 12 days. At the end of this time the powders had lost a great portion of their odor but were still active against roaches.

The following tests were made on 300 grams of powder to see what amount of extract different solvents would remove when used one after the other in a Soxhlet extraction apparatus. The succession used was petroleum ether, chloroform, acetone, and 95 per cent alcohol:

Solvent.	Extract.
	Per cent.
Petroleum ether	3.4
Chloroform	5.0
Acetone	6.2
Alcohol	9.0
Total	23.6

Fifty-gram portions of coarsely-powdered material (made from partially open flowers) were then completely extracted in Soxhlet extraction apparatus by various organic solvents. The object of these extractions was to determine what solvents would remove the active principle and at the same time extract as little as possible of the other substances. In nearly all cases a quantity of resinous material separated from solution after the extraction had been running for some time. This resinous material, which would not go into solution, even when treated with large quantities of the solvent, apparently resulted from the polymerization of unstable terpenelike substances extracted by the solvent, a polymerization probably induced by the heat of the boiling solvent.

After extraction the material was tested on roaches, ants, and other insects by the entomologists of the Bureau of Entomology, of this department, at the Vienna testing laboratory, Vienna, Va. In all cases the extracted material was entirely inert when tested against these insects, showing that all the solvents used completely remove the insecticidal principle.

Table 46 shows the solvents used, the total amount of extracted material removed by each solvent, and the amount of insoluble resin separating out in each case.

TABLE 46.—*Amount of material extracted by various solvents from the flowers of C. cinerariæfolium (Sample No. 26962).*

Solvent.	Total extract.	Insoluble resin.
	Per cent.	*Per cent.*
Chloroform	8.93	0.04
Carbon tetrachlorid	6.51	.80
U. S. P. ether	7.85	.77
Petroleum ether	3.77	.37
Carbon disulphid	4.57	.62
Methyl alcohol	28.78	11.38
Ethyl alcohol (absolute)	19.18	1.12
Ethyl alcohol (95 per cent)	30.91	4.18
Acetone	16.66	2.20
Benzol	5.74	.00
Ethyl acetate	15.48	1.30

No insoluble resin is formed in extracting with benzol, and only a trace with chloroform. The large amount of insoluble extract in the case of methyl alcohol is explained by the fact that the solution went nearly to dryness through loss of the solvent by evaporation.

In view of the fact that all the solvents completely removed the insecticidal principle, as shown by practical tests, and petroleum ether extracted the smallest amount of material, it was decided to use petroleum ether as the solvent in further work and to use a percolator in making the extractions, to avoid heating the material in solution.

For the percolation a quantity of the highest grade closed Japanese insect flowers procurable were coarsely powdered, packed in a glass percolator, macerated with the solvent for 48 hours, and the percolation then allowed to proceed slowly, the solution being drawn off at the rate of about 1 drop a second. In this way a beautiful, slightly greenish-yellow solution was obtained. This was placed in large glass crystallizing dishes, and the solvent allowed to evaporate at room temperature in a current of air. The residue remaining was partly solid and partly an oily liquid, at ordinary temperature, of a reddish-yellow color, and had a strong characteristic odor. Nothing crystalline was observed in this residue. Careful tests showed that it did not contain any nitrogen.

PROCEDURE 1.

For further separation of the materials present in this residue, the entire material extracted by the petroleum ether was saponified by boiling with alcoholic potash (22 grams of potassium hydroxid and 600 cc. 95 per cent alcohol to 32 grams of extract). The boiling was continued for 75 minutes, the alcohol removed by evaporation on the steam bath, the residue taken up in water, and the alkaline solution extracted with ether. The ethereal extracts, which were of a beautiful reddish-yellow color, were combined, washed with a little water, dried over calcium chlorid, and the ether removed by evaporation at room temperature in a current of air. A mass of reddish-yellow powder was left. On recrystallizing this powder from alcohol, the first recrystallization removed all of the red color, and the second all but a trace of the yellow color, leaving crystals of a very pale yellow. The melting point of these crystals (167° to 168°) and tests for a phytosterol showed it to be a phytosterol-like substance. Tested upon insects (roaches, ants, and aphides), it proved to be inert.

The mother liquors from the recrystallizations were evaporated to dryness in a vacuum desiccator over sulphuric acid. More of the phytosterol-like substance was obtained, but nothing else. This was also found to be inert against the insects mentioned. The insecticidal principle of Pyrethrum flowers is not, therefore, in the non-saponifiable portion of the petroleum-ether extract.

The solution from the saponification after extraction with ether was made slightly acid with sulphuric acid, and again extracted with ether. These extracts were very dark red, almost black. After washing with a little water, drying over calcium chlorid, and evaporating the ether at room temperature in a current of air a sticky resin was left. Special tests were made for phenols in this material, but the results were negative. Tests on small portions with various solvents failed to yield any crystalline product.

The whole of the saponifiable portion was then dissolved in U. S. P. ether, and about twice its volume of petroleum ether added. This precipitated a very dark, sticky resin, which was filtered off. Tested upon aphides, this resin proved to be inert.

The filtrate from this resin, which contained the fatty acids, was evaported to dryness, leaving a soft, yellowish, oily, sour-smelling residue. This material was shown to contain acetic and other fatty acids, together with a pungent-tasting oily substance which was present in too small an amount for further investigation. When sprayed upon aphides feeding on nasturtium plants, the fatty acids injured the leaves of the plants, but the aphides were unaffected.

These tests show that saponification with alcoholic potash produces a chemical change which destroys entirely the insecticidal action of the material. That saponification with alcoholic potash effects chemical decomposition in some of the compounds present is also shown by the fact that petroleum ether added to the U. S. P. ether solution of the saponifiable portion precipitates a resin, whereas all the material before saponification was soluble in petroleum ether.

PROCEDURE 2.

Since saponification with alcoholic potash destroys the insecticidal action of the material extracted by petroleum ether, another procedure was adopted. A petroleum-ether extract was obtained as before, evaported to dryness, and taken up in U. S. P. ether. This ethereal solution was successively extracted with aqueous solutions of ammonium carbonate, sodium carbonate, and sodium hydroxid, made up on the basis of 10 grams of salt to 100 cc. of solution. The ammonium carbonate solution assumed a light yellow color when shaken with the ethereal solution of the extract. Emulsions which were difficult to separate formed. After repeatedly extracting with ammonium carbonate and washing with water, the ethereal solution was separated, and reserved for the sodium carbonate extraction.

The ammonium carbonate solution was made acid with sulphuric acid and shaken with ether, which slowly and apparently incompletely took out the yellow color. On evaporating this ether extract to dryness, after washing and drying over calcium chlorid, a few greenish-yellow, oily, sticky drops were left. From 1,920 grams of powdered flowers only 0.345 gram of material was thus obtained. This amount was too small for purification and chemical testing, and was, therefore, used for testing on insects. It was dissolved in about 50 cc. of 95 per cent alcohol, diluted with an equal quantity of water, and sprayed on nasturtium plants which were infested with aphides. From 75 to 80 per cent of the aphides were killed. In check tests with 50 per cent alcohol no aphides were killed.

The aqueous solution of sodium carbonate removed a noticeable amount of a brownish-yellow material, which was obtained as a sticky mass after acidifying and extracting with ether. Tested against aphides in the same way, the material proved to be very active, killing 100 per cent. Extraction with sodium hydroxid solution removed a quantity of chlorophyll and also some of the insecticidal constituents. About 80 per cent of the aphides sprayed with an aqueous alcoholic emulsion of the extracted material were killed. On evaporating the ethereal solution of the original petroleum-ether extract after these successive extractions with aqueous ammonium carbonate, sodium carbonate, and sodium hydroxid, a strong reddish-orange pasty material was left. Tested on aphides, this material likewise exhibited marked insecticidal power, killing about 90 per cent of the insects.

These tests show that the active principle can not be wholly acidic or phenolic in nature; otherwise all would have been extracted by the aqueous sodium hydroxid solution.

PROCEDURE 3.

In this procedure the petroleum-ether percolate was not evaporated to dryness, but was first extracted with a saturated aqueous solution of sodium bisulphite to remove aldehydes, if present, and then with 1 per cent sodium hydroxid.

On acidifying the sodium bisulphite extract with sulphuric acid, extracting with ether, and evaporating to dryness, a trace of a sticky varnish was obtained. This had a pleasant odor, gave a somewhat indefinite test for aldehydes, and appeared to be a polymerization product. The amount obtained was too small for satisfactory testing, but apparently a very small amount of aldehyde is present in the petroleum-ether extract of insect flowers. The sodium hydroxid extract contained a quantity of chlorophyll, and in other respects resembled very closely the sodium carbonate and sodium hydroxid extracts obtained in Procedure 2.

The residual petroleum-ether solution, after successive treatment with the bisulphite and hydroxid of sodium, was evaporated to dryness, and left a sirupy, reddish material similar to the residue obtained in Procedure 2.

IDENTIFICATION TESTS ON THE MATERIALS ISOLATED IN PROCEDURES 1, 2, AND 3.

These extracts were subjected to a number of special tests as outlined in Mulliken's "Identification of Pure Organic Compounds" and other standard works, the details of which it is unnecessary to repeat here. By means of these tests it has been shown that the petroleum-ether extract of the flowers of *C. cinerariæfolium*, which completely removes all substances of insecticidal action, contains no ketones, no phenols, and no nitrogen-bearing compound, but that it consists largely of an ester, together with a trace of aldehyde and a quantity of free acids.

These results harmonize some of the discrepant conclusions reached by previous investigators, especially Schlagdenhauffen and Reeb, who claim that the active principle is an acid, to which they gave the name of pyrethrotoxic acid, and Fujitani, who claims that it is a neutral ester, which he named pyrethron.

DISTRIBUTION OF THE ACTIVE PRINCIPLE IN CHRYSANTHEMUM CINERARIÆFOLIUM.

It has long been known that the flowers of the *Chrysanthemum cinerariæfolium* possess insecticidal properties. The action of the stems is so slight that they are practically worthless as an insecticide. It has been generally supposed that the buds, or "closed" flowers, were more active than the mature or "open" flowers. In the trade, insect flowers are divided into 3 grades: "Closed," "half-closed," (or "half-open"), and "open." The "closed" flowers are usually sold for about twice as much as the "open" flowers, which would imply that their insecticidal power is correspondingly greater.

Of those who have conducted investigations on the active principle of insect flowers, Gerard (93) is the only one who states in what part of the flower it is chiefly found. According to him, there are 2 active substances, an oleoresin and an essential oil, which are found principally around the ovaries of the flower, and to a small extent in the corollas.

The work on insect flowers and stems here reported, in which it is shown that the nitrogen content increases with the grade of the product, led to a determination of this constituent in the different parts of the flower, and at the same time a test of these same parts on insects to see if the insecticidal effect was related in any way to the amount of this element present. Some typical commercial "open" flowers (*C. cinerariæfolium*) were obtained, and dissected into their principal parts. In most commercial samples, the greater number of the flowers have lost their disc and ray flowers, and consist only of fruit receptacles, and involucral scales. The fruit amounted, on the average, to 80.5 per cent, the receptacles to 10.8 per cent, and the involucral scales to 8.7 per cent of the whole flowers. Enough disc flowers were collected to determine their nitrogen content, but these were lacking in so many of the "open" flowers that their natural relative proportion could not be determined. Their normal actual percentage by weight, however, is very small. The results of the analyses are given in Table 47.

TABLE 47.—*Determination of nitrogen content of insect flowers.*

Sample.	Nitrogen.	Percentage of total nitrogen.
	Per cent.	
Entire open flower	1.26	
Fruit	1.40	89.4
Receptacles	.67	5.7
Involucral scales	.51	3.5
Disc flowers	1.68	

The nitrogen in the fruit of 5 other samples of "open" flowers was also determined, with the following results:

TABLE 48.—*Nitrogen in fruit and flowers of insect flower plants.*

Fruit.	Entire "open" flower.
Per cent.	*Per cent.*
1.34	1.31
1.32	1.22
1.34	1.28
1.24	1.25
1.26	1.25

From these results it is seen that the fruit from commercial samples of "open" flowers contains about 90 per cent of the total nitrogen.

Practical tests were made by E. W. Scott and W. S. Abbott, of the Bureau of Entomology, on roaches with the different parts of the finely-powdered flowers, to determine their relative insecticidal strength. The roaches were dipped in the powder until all parts of the body were covered with it, and then placed in 8-ounce bottles, one insect to a bottle, 10 insects being used in each test. All of the insects were allowed ventilation, but no food or water. The average of the 10 tests in each case is given in Table 49.

TABLE 49.—*Insecticidal strength of finely-powdered parts of insect flowers.*

Sample No.	Source.	Time required to paralyze.	Time required to kill.
		Minutes.	*Hours.*
1	Entire "open" flowers of *C. cinerariæfolium*	3.7	21
2	Fruit from sample 1	2.4	19½
3	Ray flowers from sample 1	1,800	63
4	Receptacle from sample 1	90	50½
5	Involucre from sample 1	240	80
6	Disc flowers from "closed" flowers of *C. cinerariæfolium*	8	31½
7	Stems		131
8	Flowers of *C. roseum*	7	23
9	Check		236½

Apparently the fruit and disc flowers of the *Chrysanthemum cinerariæfolium* are the parts most active in paralyzing and killing roaches. These are the same parts that show the highest content of nitrogen, so that this element, although not actually a constituent of the active principle, appears to be present with it in a constant ratio, and hence can be used as a measure of the insecticidal activity.

Summary of work on the active principle.—All of the common organic solvents completely remove the insecticidal principle from the flowers of the *C. cinerariæfolium.* The insecticidal principle is not removed by a steam distillation, either in neutral, acid, or alkaline solution. It is insoluble in water and dilute acids, but dilute potassium hydroxid solution removes nearly all of the activity from the powdered flowers. It is shown conclusively that the active principle contains no nitrogen and is not an alkaloid. A considerable amount of resin is present in Pyrethrum, but this is inert when tested upon roaches. Alcoholic potash saponification completely destroys the insecticidal activity of the petroleum-ether extract, the ester being split up into acids and resinous materials. The results of the work indicate that the insecticidal activity of Pyrethrum is due to a mixture of acids and esters.

SUMMARY.

The fact that flowers of certain species of Pyrethrum possess the property of killing various insects was known to the people of eastern Europe more than a century ago. Since that time this knowledge has gradually spread, until insect powder is now a common household convenience. This powder owes its insecticidal activity to a mixture of acids and esters which first benumb and subsequently kill the insects brought into contact with it. While it is generally considered to be harmless to the higher animals, a number of cases where it has produced symptoms of a more or less serious nature are recorded.

At present insect flowers are cultivated commercially in Dalmatia, Japan, Australia, Algeria, and California in the United States, the first three countries producing nearly all of the flowers that enter into international trade. The powder is made in each of these countries.

In the enforcement of the Insecticide Act, insect powder has been found adulterated in a variety of ways. In some instances such substances as lead chromate, curcuma, and yellow ocher are added to give color. Other species of flowers, like the Hungarian or oxeye daisy, are substituted in whole or in part for the true insect flower, while almond shells, brick dust, hellebore, pepper, sawdust, starch, sumac, and the like have been found less frequently in samples examined. The ground stems of the Pyrethrum plant, however, probably constitute over 95 per cent of the adulterants used in insect powder at this time.

Physiological, chemical, and microscopical methods which can be used satisfactorily in detecting adulteration with powdered stems have not as yet been perfected to such a degree as to make an accurate quantitative determination possible. However, from the data obtained in the examination of hundreds of samples of genuine insect powder, of the materials used for its sophistication, and of commercial samples, the results of which are reported in this bulletin, a formula, given on page 58, has been developed by which it is possible to determine in an insect powder the approximate amount of added Pyrethrum stems present.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 825

Contribution from the Bureau of Markets
GEORGE LIVINGSTON, Acting Chief

Washington, D. C. ▼ **January 30, 1920**

RURAL COMMUNITY BUILDINGS IN THE UNITED STATES.[1]

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GROWING INTEREST IN COMMUNITY BUILDINGS.

Throughout the country there is a keen and widespread interest in community buildings, their activities, their accomplished results, and their possibilities. Their development is so recent and they are so essentially an outgrowth of rural life and conditions that knowledge regarding them necessarily has been fragmentary, in most cases limited to impressions gained from observation of a few isolated houses. The construction and acquisition of special buildings to serve as community centers is such an important result of social organizations in the rural sections and smaller towns of the United States that a comprehensive study of a number of representative buildings was deemed desirable by the Department of Agriculture. Accordingly a study has been made of 256 such buildings. Most of them are relatively new, 248 having been built since 1900, 201 since 1910, and 90 since 1915. The accompanying diagram (fig. 1), based on the date of construction reported for the buildings studied, shows the increase in the number of community buildings from 1900 to 1918. The figures are taken in each case for the end of the year indicated. As shown by the diagram, more than one-half of the buildings for which data are available were constructed between 1912 and 1916.

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[1] On July 1, 1919, the study of rural social organization, including rural community buildings, was transferred to the Office of Farm Management, and Mr. Thompson assumed charge of the Division of Cooperative Marketing.

Of the total number of buildings studied 201 are in places of 2,500 inhabitants or less, 83 being in the open country, and 55 are in towns or small cities having a population of more than 2,500. Twenty-five are school community buildings and 29 are church community buildings, 20 of the latter being in buildings separate from the church. Nine are farmers' fraternal society buildings and eight are library and community buildings.

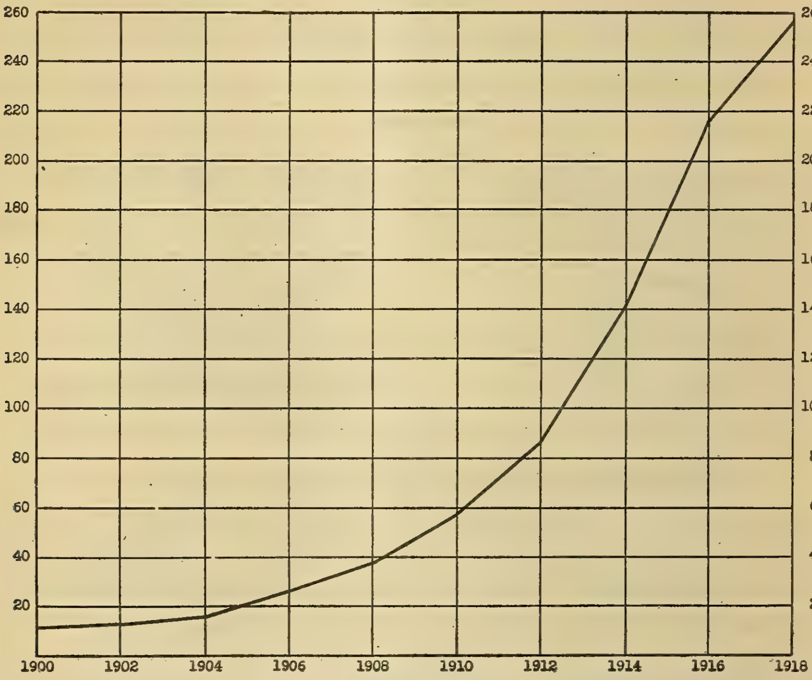

FIG. 1.—Increase in number of rural community buildings, 1900 to 1918, according to data obtained by the Bureau of Markets.

COMMUNITY BUILDINGS CLASSIFIED ACCORDING TO SOURCE OF FUNDS FOR THEIR ESTABLISHMENT.

The amount of money invested in these buildings varies according to the population and wealth of the community and the method of financing, and ranges from $2,000 in sparsely settled communities, where considerable amounts of labor and materials are often donated, to $50,000 in the small cities.

Based on methods of financing, the buildings may, in a general way, be separated into the five following classes, although, on account of overlapping or combination of methods, the dividing line is not always distinct.

1. *Buildings financed by a local manufacturing concern.*—In a number of communities social center buildings have been erected by a manufacturing concern, usually one which represents the predominating industry of the community. Local assistance has been given in some cases, but usually the manufacturing concern has borne the whole expense, or practically the whole of it, having in mind the welfare of its employees and of the community on which it depends for support. These buildings are generally maintained and managed by a community organization formed for the purpose, and the title to the building is often turned over to this organization.

2. *Buildings financed through individual donations.*—A considerable number of community buildings have been presented outright by individuals, some of these taking the form of memorial buildings. Other buildings have been financed partly by large individual donations and partly with funds raised by the community in general. The donated buildings are usually turned over to an appropriate community organization, though some remain under the management of a self-perpetuating board of trustees.

3. *Buildings financed through club or society initiative.*—When buildings have been financed through club or society initiative the major share of the financial burden has been assumed by a specialized organization, which has projected a building primarily for its own use, but available also for general social purposes. Such buildings have been erected through the efforts of athletic associations, women's clubs, and other types of organizations. The building erected by a farmers' club in a strictly rural community becomes automatically a building for the community as a whole, since the club membership often embraces practically the entire population of the community. The ownership and control of buildings in this class rests, as a rule, with the organization responsible for their construction, or with a special organization which has been formed to take care of the increasing activities centering in the building.

4. *Buildings financed by the local government.*—The buildings in the fourth class are financed by county, town, or township governments, the funds for construction being obtained either through taxation or from the sale of bonds. Such buildings are usually maintained, at least in great part, through rentals and other revenues derived from the building itself. The title and control remain with the governmental unit originally responsible for the building.

5. *Buildings financed through community endeavor.*—The most numerous group in the present classification comprises buildings constructed or acquired by the community for community purposes. Money is usually secured either by the sale of stock in a community organization or through the solicitation of general contributions. Both of these methods are often supplemented by the giving of enter-

tainments of various kinds, the proceeds of which go into the construction fund; and a part of the amount required to pay the cost of construction is often borrowed on the security of the building itself, to be repaid later with money derived from dues, assessments, or rentals. Contributions of labor or materials, as well as of cash, are often received. Where funds are secured through the sale of stock, the incorporated stock company of course owns or controls the building; and where funds are secured through general contributions the ownership and control rest with a permanent community organization formed for the purpose.

GENERAL CHARACTER OF THE BUILDING.

The simplest of these buildings, often found in the open country, generally contain, first, an auditorium, the movable seats of which permit it to be transformed into a dining room, an athletic room, or a hall for dancing; second, a stage, with curtains and dressing rooms for theatricals; third, a kitchen, equipped with stove, utensils, dishes, and cutlery. Often the assembly room is on the first floor and the kitchen and a separate dining room in the basement. Farmers' buildings frequently contain special rooms for the use of cooperative economic enterprises.

In the smaller towns, besides these rooms there are often a library and reading room, a game room, a women's rest room, and rooms which serve as meeting places for various organizations.

In the county seats and larger towns the buildings are often quite complete, having besides the usual rooms an office room, special rooms for banquets, a café, a gymnasium, billiard and bowling rooms, an agricultural exhibit room, and rooms for the county agricultural agent, the county home demonstration agent, the visiting nurse, and the secretary of the commercial club. Community buildings provided by town or county government also contain rooms for the different officials, the post office, and sometimes a social room for the fire department.

Equipment in these buildings varies from the plain chairs and tables, stove, cooking utensils and dishes, and organ of the simpler structures, to the fine furniture, opera chairs, stage scenery, gymnastic, bowling, billiard, athletic and game-room apparatus, books and magazines, piano, moving-picture machine, and first-aid facilities of the finer ones. Those in the open country are generally heated by stoves, lighted by oil or gas lamps, procure water from their own pumps, and have outside toilets, while those in the towns have furnace heat, electric lights, running water, inside toilets, and hot and cold baths.

The sites in both town and country range from a size little larger than the building to one of several acres. Those with the larger sites are often provided with baseball diamonds, tennis, volley-ball and basket-ball courts, tracks, and athletic fields, and equipped with playground apparatus. Many buildings, both in town and country, have horse sheds or garages on the premises.

MAINTENANCE.

In case of the simpler buildings, maintenance expenses range, in general, from 5 per cent to 10 per cent of the initial cost of the plant, the expenditures of the less expensive being chiefly for light and heat, while to these are added, in case of those involving larger maintenance expenses, water rent, telephone, and similar expenses, and salaries for secretaries or physical director, caretaker, and librarian.

Funds for maintenance are secured through dues, fees, assessments, rentals, receipts from entertainments, dances, moving pictures, bowling and billiards, and, in case of publicly constructed buildings, by money voted from the public treasury.

OPERATION AND MANAGEMENT.

The persons owning stock in community buildings generally organize and constitute themselves a community building association. They frequently take out articles of incorporation giving them power to buy land, borrow money, and erect and control such buildings. Nonstockholders using the building are associated as social members, both classes paying dues. The stockholders, and in some instances the social members, elect a board of trustees of from three to nine members, who control and manage the building. Either the same body or the board itself elects the usual officers, such as president, vice president, secretary, and treasurer. Committees with various duties are either appointed or elected. Immediate duties of management are often delegated to a house secretary, physical director, or caretaker. In a few instances, in cases of buildings presented by an individual or an industrial concern, control is placed in a select board, nominated by the donor, and possessing power to appoint its successors. Township and city buildings are managed by the usual public officials.

USES TO WHICH BUILDINGS ARE PUT.

These buildings have become the centers of their communities for recreational, gymnastic, athletic, social, and welfare work, and often for political, cooperative business, and religious work. The following list indicates the more important of the specific uses of buildings.

Economic: Canning demonstrations, boys' and girls' club work, domestic science, agricultural society meetings, fairs, cafés, cafeterias, farmers' institutes, and cooperative purchasing and marketing activities.

Educational and recreational: Lectures, moving pictures, night schools, entertainments, billiards, pool, bowling, table games, reading room, and library.

Social: Dancing, banquets, suppers, club meetings, socials, and parties.

Athletic: Baseball, basket ball, and tennis.

Political: Political meetings and elections.

Hygienic: Nursery, welfare work, and rest rooms.

Religious: Union church work.

Gymnastic: Activities of the gymnasium.

In addition to the organizations already mentioned as using the buildings, the following were also found: Parent-teacher association, commerce club, board of trade, women's club, county agricultural society, town board, Daughters of the American Revolution, Young Men's Christian Association, Young Women's Christian Association, Woman's Christian Temperance Union, Grange, Farmers' Educational and Cooperative Union of America, Society of Equity, choral society, athletic association, various fraternal organizations, Farmers' League, art club, driving association, hospital corps, Young People's Christian Association, industrial club, dairy association, civic association, fire department, poultry association, men's club, relief society, ladies' aid society, Young People's Society of Christian Endeavor, Sunday school, cooperative marketing association, and county medical society.

SPECIFIC EXAMPLES OF COMMUNITY BUILDINGS.

In the following pages are presented brief statements relative to the origin, purpose, and present use of typical community buildings. These buildings have been chosen with a view to showing examples of community buildings constructed or acquired under a variety of conditions and serving different types of communities. It is believed that the concrete story of how some one community actually secured and used a community building will often prove more suggestive to other communities interested in the question than any statement in the form of a composite summary or tabulation of the results of the investigation of many buildings.

THE COMMUNITY HOUSE, HOLDEN, MASS.

The community house of Holden, Mass., together with the organzation connected with it, is an example of the revival of civic pride, public spirit, and true neighborliness in a small but very old New England rural community. Among the immediate causes contributing to the enterprise were, first, a developing movement toward expansion along social lines, as indicated by the organization of several societies with various social objects but with no adequate meeting place; and second, the fact that an important piece of private property, which in times past had been a tavern of low repute, was about to be converted again into a cheap lodging house. The property in question was a fine old three-story colonial mansion, built on land formerly the property of John Hancock, in the heart of the town adjacent to the town hall, the library, and the principal church.

In May, 1914, a group of local leaders, including representatives of the Congregational Men's Club, the Baptist Men's Club, the Village Improvement Association, the Daughters of the American Revolution, the Boy Scouts, the Tuesday Afternoon Club, and the Fifteen Club, met and formed a temporary organization under the name of the Holden Community House Association.

They issued a circular which gave the object of the association; recited the fact that the Boy Scouts, the Camp Fire Girls, and the Grand Army of the Republic were in immediate need of a meeting place; gave the detailed plan, with items of expense, for the purchase and reconstruction of the old mansion as a community house; stated the amount of money which would be needed and the proposed method of raising it; and closed with a request for immediate subscriptions for shares of stock.

After the initial work was accomplished, the temporary organization developed into a corporation chartered under the laws of Massachusetts as a real estate handling corporation "to acquire, hold, manage, develop, improve, lease, mortgage, buy, or sell real estate."

The specific aim of the people who sponsored this building was to provide a house which, without particular consideration for class, party, or creed, would serve community needs and provide—

1. An assembly place for the various social organizations of the community. A count made at the initial meeting showed 22 organizations which might be expected to use the building.

2. A place where the people might gather for recreation through games, reading, banquets, and other forms of social relaxation.

The cost of the building was as follows:

Three-fourths acre site and building, including furniture	$3,500
Sale of outbuildings for	500
Outlay after sales of outbuildings	3,000
Renovations, consisting of new floors, decorating, painting, etc., electric light, and steam heat installations, and lavatories	2,000
Total cost	5,000

Since the purchase of the building a piano has been bought for $225, while various gifts of furniture have been received.

The house is of brick, three stories in height, and of colonial type of architecture. It is painted a colonial buff on the outside, with white trimmings. Care was taken during repairs to retain the fireplaces in all the rooms. Other colonial features are the Dutch oven, old window casings with green shutters, a wide veranda across the front, and cupola on the top. The stairways are in the center of the house, ascending from halls which extend the length of the building.

On the third floor are five living rooms, occupied by the family of the caretaker.

On the second floor are found a reading room, 16 by 18 feet, on the left front, containing 3 card tables, a reading table, 2 large leather-covered easy chairs, 8 leather-bottomed straight chairs, 4 straight wooden chairs, a large center rug, and 5 wall pictures; a pool room, at the right front, 18 by 28 feet, containing 2 pool tables with racks, and a half dozen folding chairs; a Boy Scouts room, 16 by 18 feet, at the rear of the reading room, containing various games, a bookcase, a shelf closet, 25 folding chairs belonging to the scouts, and wall pictures; a kitchen, 16 by 18 feet, at the rear of the pool room, with a dumb waiter extending to the lower floor and with utensils and dishes sufficient to serve 170 people, also 2 dish closets, sinks, wash tables, drawers, etc., a large cookstove, together with 2 oil stoves and center tables which are the property of the village school.

On the first floor are the following rooms: On one side of the central hall, an assembly room, 20 by 39 feet, with a seating capacity of 100, with a hardwood dancing floor, furnished with 50 folding chairs, a piano, 2 wicker tables, a large clock, and 2 large wall pictures; a public reading room across the hall from the assembly room, stocked with papers and magazines and furnished with a large table, a dozen arm chairs, a wicker chair, and a large rug; 2 dressing rooms at the rear of the assembly room; and a tea room at the rear of the reading room, which accommodates 50 people.

The basement contains a large storeroom and the furnace room.

Funds for the acquisition of the building were obtained as follows:

From sale of 532 shares of nonassessable stock to 131 holders at $5 per share	$2, 660
Individual loan	1, 550
Total	4, 210

A floating indebtedness of $500 was covered by a further sale of one share of stock to each holder.

Five hundred dollars also has since been paid on the loan.

The janitor for his services receives the third floor, rent free, for living rooms, and free electricity, heat, and water, the latter items amounting to about $25 per year. Other expenses are as follows:

Coal, per year	$200
Electricity, per year	70
Taxes, per year	77
Miscellaneous	78
Total	425

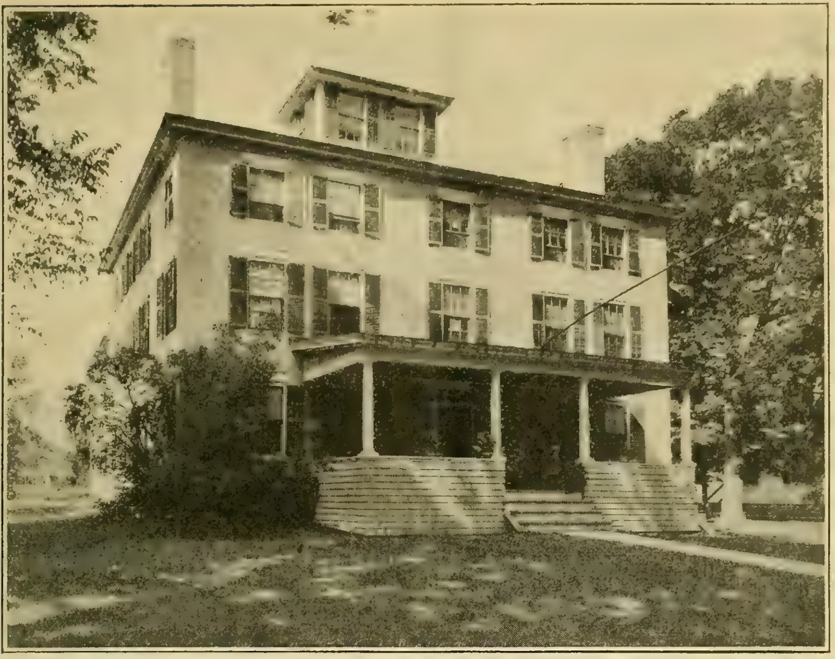

FIG. 2.—Holden (Mass.) community house.

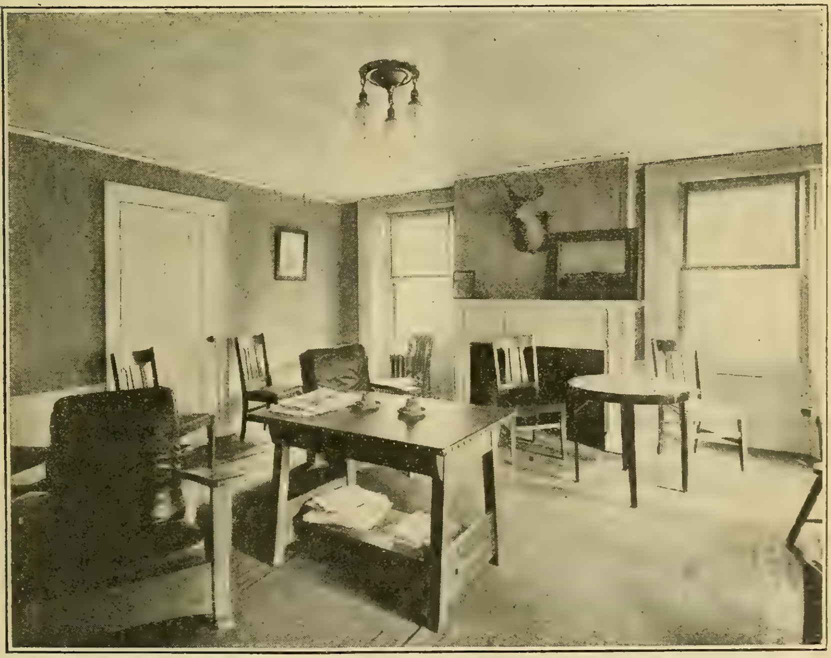

FIG. 3.—Holden (Mass.) community house, public reading room.

It is hoped that a further sale of stock will make it possible to house all organizations free, but at present expenses are met by nominal rentals.

Formerly it was necessary to give entertainments to provide money in addition to the receipts from rentals, to meet expenses. Now the rentals approximately meet expenses as follows:

Boy Scouts, per year	$60
Municipal school, kitchen for domestic science	50
Town club, rental of reading room and pool room, heated, lighted, and cared for, per year	260
Miscellaneous rentals, per year	55
Total	425

The assembly room, tea room, and kitchen are rented to outside parties for $5.50 per night, to local parties for $3 per night.

The Daughters of the American Revolution and the Woman's Club pay a stated rental per meeting.

The building is owned by the Holden Community House Association, incorporated for 50 years, with capital stock of $10,000, and empowered to issue stock at $5 per share. The officers of the corporation are a board of directors consisting of 9 stockholders, including a president, a clerk, and a treasurer, all of whom except the president are chosen by ballot annually by the corporation. One of the board is chosen president by the directors. The management of the property and business of the corporation is in the hands of the board of directors. The caretaker is approved by the board, which also appoints a house committee of three members, and may appoint other committees.

As a result of having an adequate meeting place, the Town Club, a men's organization with 65 members, was formed, with social, recreational, and civic aims. It rents annually several rooms. Likewise the two women's literary clubs united and formed one organization of 84 charter members which meets in the community house. A community orchestra has also been organized and meets for practice in the building.

Other organizations which meet there regularly are the Daughters of the American Revolution, the Boy Scouts, the Red Cross, and the Equal Franchise League.

As the high school did not have the proper facilities, there was no course in cooking. Now such a course has been added to the curriculum, and the school board rents the kitchen in the community house for the cooking class at a nominal expense. Every girl in the high school who is eligible to this course has elected to take it.

Private parties, dances, luncheons, card parties, illustrated lectures, and entertainment courses are frequently given in this building.

Under the management of the directors a series of high-class entertainments at low cost has been given. Folk dances and lawn parties have been featured. Officials say the building stimulates idealism, fosters local pride, and prevents deterioration of town morals.

THE MATINECOCK NEIGHBORHOOD HOUSE, LOCUST VALLEY, LONG ISLAND.

About eight years ago a boy came to the secretary of the Matinecock Neighborhood Association and asked him to start a boys' club, saying that there was no place for the boys to go for a good time except to the saloons or to the neighboring town with its questionable amusements. The secretary, who had but recently arrived, made a survey of the situation. He found that through economic changes, farming was gradually being given up and the section was becoming a residential one. The population was shifting, and neighborhood spirit and community recreation were at a low ebb.

He found also that there was in the village a private unsupervised young men's athletic club which met in a blacksmith's shop. Being a man of vision, he determined to make this club a nucleus of a general system of supervised recreation for the village with a community house as a center.

He persuaded the athletic club to sign a petition for the Neighborhood Association to take them in as members on payment of the regular dues, $1 per year, and then to commission them as a recreation department to furnish recreation for the whole community. The association complied and appointed an executive committee, composed of two of its directors and five young men, to have charge of the arrangements. Twenty-nine boys were appointed on committees in order to give them a share in the constructive work.

Temporary quarters were secured in an old barn, which was fitted up through general contributions, including a graphophone, a piano, a pool table, stoves, dishes, an indoor baseball outfit, $137 in cash, and subscriptions for many magazines. Boy Scouts and a band were soon organized, and other organizations were formed.

As a result, it was soon found that 148 young men were governing themselves, financing their own enterprise through various entertainments, and providing social opportunities and athletics for their fathers, mothers, brothers, and sisters. At the same time they were members of the Neighborhood Association, with votes on all questions pertaining to it.

The barn soon became too small for these various activities. This brought to the front a question which had been under consideration for some time, the erection of a community building. It was finally decided that a building should be erected which would be the headquarters of the Neighborhood Association, with its membership of

300 men and women, representing 235 families, together with its boys' recreation department, and also be a general social center.

The keynote of the enterprise was struck by the president of the Neighborhood Association at the time the plans were presented to the association, when he said:

> It is not an easy matter to plan out this building enterprise because it has got to represent everyone in the village and be an expression of all the people. We could no doubt get a single individual or a group of individuals to put it up for us, but that is not the sort of thing we are after. When we go into this interesting edifice it will be a success only if we feel that each of us has had a hand in making it and each of us will have a hand in keeping it a thing of life, radiating friendliness and pleasure.

The completed building, together with the land, represents an outlay of $32,000. The community nature of the work was continued in the raising of funds and the method of construction, as indicated in the following summary:

Site of 2 acres donated by five members	$3, 200
Voluntary labor of 110 members	1, 500
Bequest to the association	2, 000
Voluntary contributions from 90 per cent of the families in the village	26, 300
Total	32, 000

The work was put in charge of a local manager who received only his expenses for the work. Subcommittees were appointed to have charge of excavating, masonry, plans, carpentry work, painting, grounds, purchasing, plumbing, and finance. All work was done by local citizens.

The building is situated on a rise of ground in a grove of trees and comprises one story and a basement. The auditorium can be made to seat 500 people and was especially designed for motion-picture exhibitions, for dances, and for basket ball. There are also a social room for pool, cards, and other games, which is used for a general informal meeting room, a committee room, two rooms for the caretaker, two coat rooms, five baths, toilets, four bowling alleys, and heater and storage rooms. In the building also is a room for the volunteer fire department and its apparatus, since the department at its own request has been made an adjunct of the association. The building is a library substation, and among the furnishings are a player piano, stoves, kitchen utensils, and billiard tables.

The house is entirely self-supporting through the earnings of the recreation department, the receipts from motion-picture shows, entertainments, dances, card parties, pool tables, bowling alleys, basket-ball games, and the rental of the auditorium for lectures and concerts.

An average of 800 people use the building weekly.

The following is a statement of receipts and expenditures for the year ending May 25, 1916, which has been selected as a representative year:

Receipts and expenditures of the Matinecock Neighborhood House, year ending May 25, 1916.

RECEIPTS.	
Bowling alleys	$698.15
Motion pictures	1,791.65
Card parties and dances	217.50
Dancing classes	138.43
Entertainments and lectures	59.60
Tennis	26.05
Pool	65.80
Tobacco stand	197.30
Miscellaneous receipts	10.16
Rental of auditorium	87.50
Rental of fire department room	252.00
Ice cream	153.44
Dues	341.60
Total receipts	4,039.18

EXPENDITURES.	
Bowling alleys	467.21
Motion pictures	1,077.43
Card parties and dances	125.38
Dancing classes	53.50
Entertainments and lectures	40.00
Tennis	16.00
Pool	.81
Tobacco stand	154.16
Miscellaneous expenses	45.63
Repairs	43.19
Equipment	131.66
Ice cream	176.90
Light	188.75
Motor	4.24
Superintendent	855.00
Grounds	126.00
Fuel	269.51
Printing	9.75
Taxes	91.32
Newspapers and magazines	2.50
Total expenditures	3,878.92
Balance	160.26

The building is the property of the association, which was organized "to promote the welfare of the residents of Locust Valley, Nassau County, N. Y., and the adjacent neighborhoods, in such manner as may be thought advisable, especially in relation to roads, water supply and lighting, drainage and general improvements, transportation, taxes, and such other matters as may be brought before the association." It will thus be seen that the association was not organized primarily to erect the building, but that the building was one of the results of the work of the association in pursuance of its general object.

The secretary of the association has an office in the building, and the various activities of the association are directed from this office. The house is managed by the house committee, each member of which is in charge of one department of the work: Women's department, tennis court and grounds, masonry repairs, carpentry repairs, accounts, bowling alleys, and entertainments. The activities of the building are under the general charge of the secretary of the association, while there is also a superintendent in direct charge of the building and grounds.

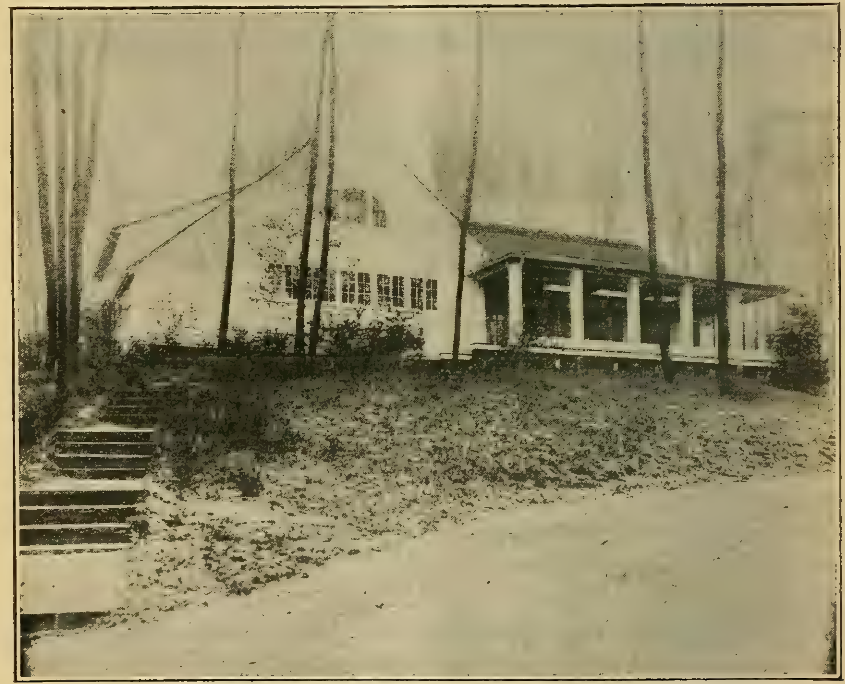

FIG. 4.—Matinecock neighborhood house, Locust Valley, Long Island, New York.

Among the activities connected with the building are the following:

Lectures, concerts, entertainments, and amateur dramatic performances occur frequently.

Weekly dancing classes are held for members and there are frequent private dances.

The bowling alleys have been in continued use, and successful tournaments have been held, each one including from 28 to 30 men and lasting three or four weeks. The women's bowling club meets weekly.

The billiard and game rooms are popular with the members.

Card parties are given frequently.

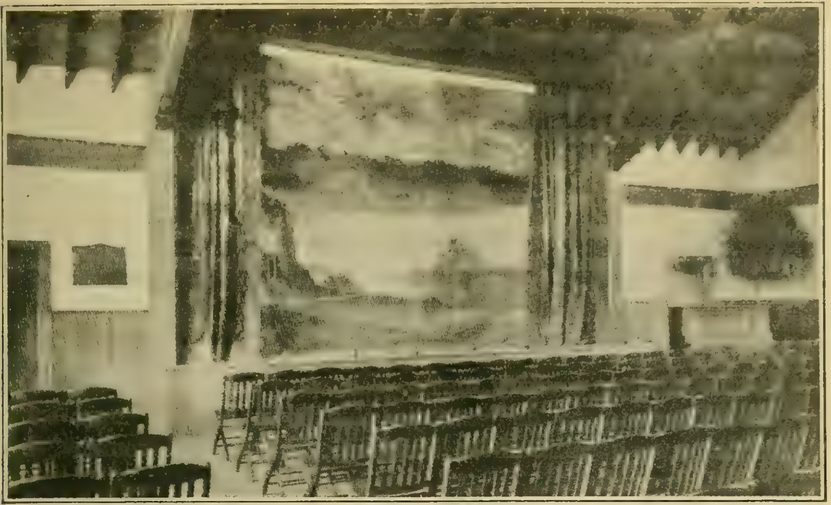

FIG. 5.—Matinecock neighborhood house, Locust Valley, Long Island, New York, auditorium.

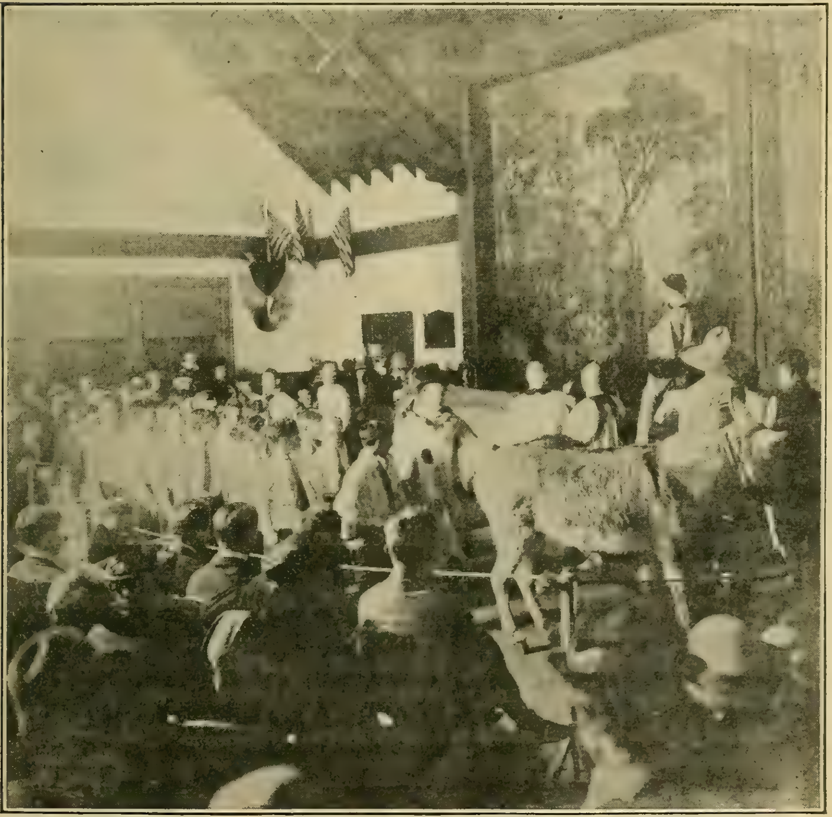

FIG. 6.—Matinecock neighborhood house, Locust Valley, Long Island, New York, circus parade.

Tennis tournaments are featured.

The women's department holds frequent sales of embroidery and other forms of needlework made by the women.

The library and reading rooms are much used.

Motion-picture shows are conducted every Wednesday and Saturday evening under the auspices of the association. Efforts are made to exhibit only the best pictures.

The house is in constant demand for farmers' meetings, school entertainments, private parties, dances, and suppers, and for use by church clubs.

COMMUNITY BUILDING, ELGIN, NEBR.

On January 1, 1917, the citizens of the little village of Elgin, Nebr., and the surrounding country met to celebrate the consummation of their united efforts; to dedicate, in this town of less than 1,000 inhabitants, a new community building, a civic achievement well worthy of their pride.

The building grew out of the fact that the town band was about to dissolve. A civic meeting was called, other civic needs became apparent, attention was centered on them by local leaders of enthusiasm and vision, community spirit was aroused, a club was deemed necessary as a working instrument, and the building was projected as a home for the club. The general purpose of the building was to serve as "a clearing house for all social activities." With this in view the opera house was bought in 1916, reconstructed, and dedicated as the social center of the town and vicinity. Among the specific objects of the building were the following:

1. A home for the community club.
2. Provision for rest and recreation facilities for town and country people.
3. A general meeting place for local organizations, public and private.
4. A place for lectures, entertainments, etc.
5. Development of civic pride and local citizenship through an open forum.
6. A public reading room and library.
7. Development of the spirit of the community through encouragement of bands, choruses, sings, etc.
8. To give representative citizens control of the amusement enterprises of the community.
9. To unite town and country forces for the welfare of both.

The cost of the building may be summarized as follows:

Original purchase of real estate and opera house	$10, 515. 00
Original purchase of furniture	735. 00
Total original cost	11, 250. 00
Cost of reconstruction, additional furniture and equipment	12, 851. 46
Total cost	24, 101. 46

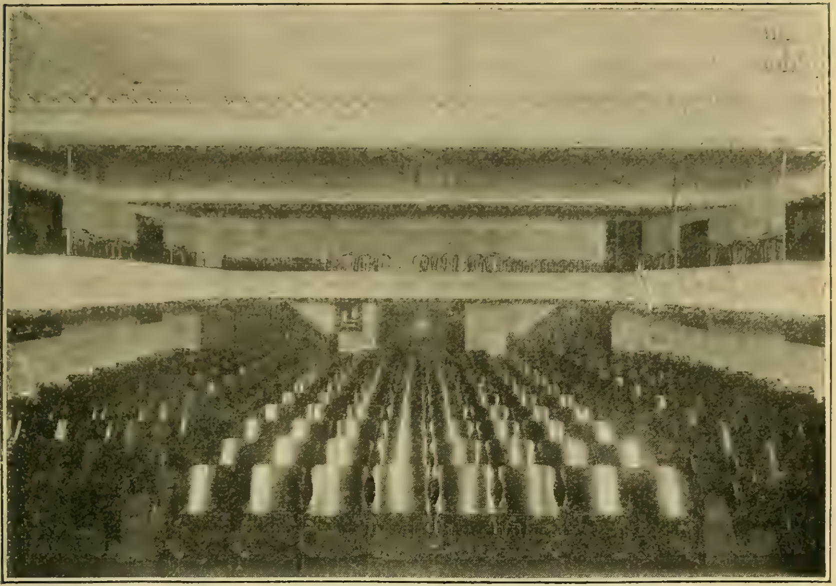

FIG. 7.—Community building, Elgin, Nebr., auditorium.

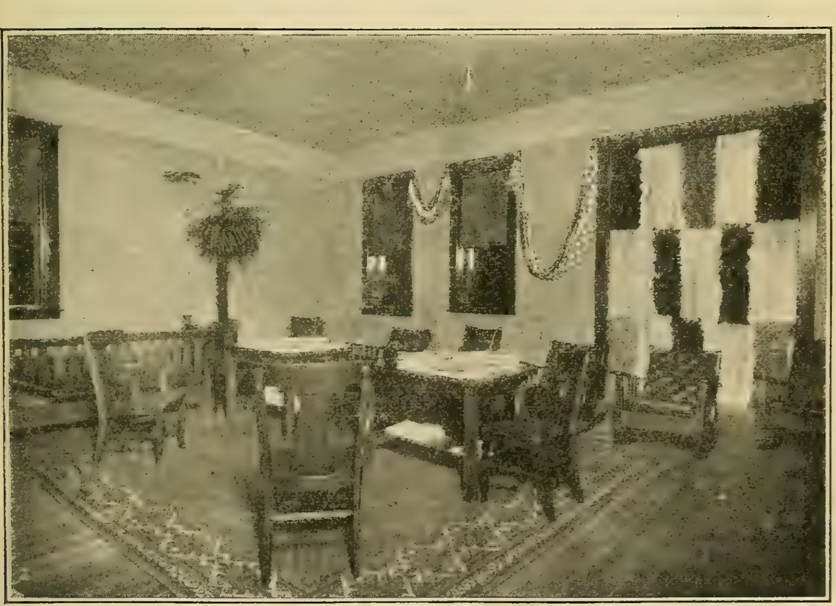

FIG. 8.—Community building, Elgin, Nebr., reading room.

A stock company was formed which issued stock to the value of $25,000, at $100 per share, with the proviso that work could not be commenced until $7,500 had been subscribed. There were 31 stockholders, owning from $100 to $1,050 each, with an average of about $300. Eleven stockholders are farmers.

Stock to the amount of $11,000 had been paid for and certificates issued at the time of dedication.

A subscription of $200 had been partially paid, and $13,800 in stock remained unsold.

There was a mortgage on the building amounting to $7,500, and floating debts in process of settlement amounting to $2,707.60, making a total debt of $10,207.60.

The building is maintained through—

1. Membership fees. These are, per year, family, $15; man, $12; woman, $2; boy, $5; nonresident, $5.
2. Admissions for entertainments and moving pictures.
3. Game fees. Bowling is 10 cents per game and billiards 40 cents per hour.
4. Rentals.

The following statement shows receipts and expenditures for the five months ending May 31, 1917:

Balance on hand January 1, 1917		$511. 33
Receipts:		
Motion pictures	$1, 333. 05	
Membership fees	492. 35	
Rents	107. 00	
Entertainments	208. 25	
Games	459. 70	
Miscellaneous	12. 50	
		2, 613. 35
Total		3, 124. 68
Expenditures:		
Motion pictures	$854. 82	
Salaries, labor, etc	777. 04	
Fuel, light, miscellaneous	529. 54	
Entertainments	269. 59	
Interest	450. 00	
Insurance	133. 40	
Taxes, etc	45. 42	
		3, 059. 81
Balance on hand June 1, 1917		64. 87

The community club consists of a double organization: First, a central holding company, incorporated, with a board of seven directors, elected annually by the stockholders, who are responsible to the State for their management of the organization. This is the stock company. They elect the usual officers. Second, the social organization, working around the corporation as a nucleus, having the same name and managed by the same officials, but having also a commissioner who looks after the comfort and welfare of the club members, operates the motion pictures, and conducts the general business of the club. There are 101 members, 42 being farmers.

It is arranged that the members of the village board of trustees, the pastors of the various churches, the superintendent of public education, and the village marshal, provided they maintain membership in the club, shall constitute an advisory board which may meet from time to time with the board of directors, to consider the various interests of the community.

The building is of brick, 40 by 80 feet, with two stories and basement. It is heated by steam, lighted by electricity, and has running hot and cold water.

On the first floor is an auditorium and moving picture room, 40 by 40 feet, containing 240 opera chairs and 60 movable chairs. At the front of the auditorium is a stage 15 by 40 feet, with a proscenium opening 14 by 21 feet, a roller curtain, and eight flies. There is also a women's rest room for members and all country women, furnished with tables, chairs, cribs, lounges, and toilet and lavatory facilities; a main lobby; the commissioner's office, which is also the box office; and a moving-picture booth of fireproof construction.

On the second floor are a reading and social room, a directors' room, a banquet hall with orchestra stage, also used as a gymnasium; a kitchen with complete equipment, a dining room and equipment, a dressing room, a lavatory, and baths. In the banquet room are 60 chairs and 8 folding tables.

In the basement are two bowling alleys, three billiard tables, a toilet room, and a furnace room.

The following organizations use the building: The Red Cross, the Boy Scouts, the Home Guards, the war loan committee, the Chautauqua company, the band, the Grand Army of the Republic, the fire department, the village board, the board of education, the ladies' club, the farmers' club, the farm bureau, private clubs, and the town library.

In addition to the activities connected with these organizations are the following: Lecture courses; weekly community club banquets, followed by business meetings; gymnasium work; recreation; games; moving pictures and traveling theatricals, contracted for and censored by the directors; local plays, musical entertainments, and recitals; a community Christmas tree; community celebrations of July 4 and Memorial Day; festivals; school exercises; private and club dances; conventions; receptions for visitors; and patriotic meetings.

RED RIVER FARMERS' CLUB HALL, KITTSON COUNTY, MINN.

Far up in the northwest corner of Minnesota, near the Canadian line, and off the railway, is a community which was established by farmers who, in the early days, came to this virgin country to pioneer a home in the wilderness. Poor in this world's goods, but of sturdy stock and ambitious for the future, for a generation their one aim was to overcome the obstacles confronting pioneer life on the prairie and build up homes for themselves and their children. The scene is now changed. The wild prairies of the fathers have become the fertile fields of the children, who, relieved of the stern necessities of mere bodily existence, find time for the higher aspirations of life. As a symbol of the new order they have erected their community club house.

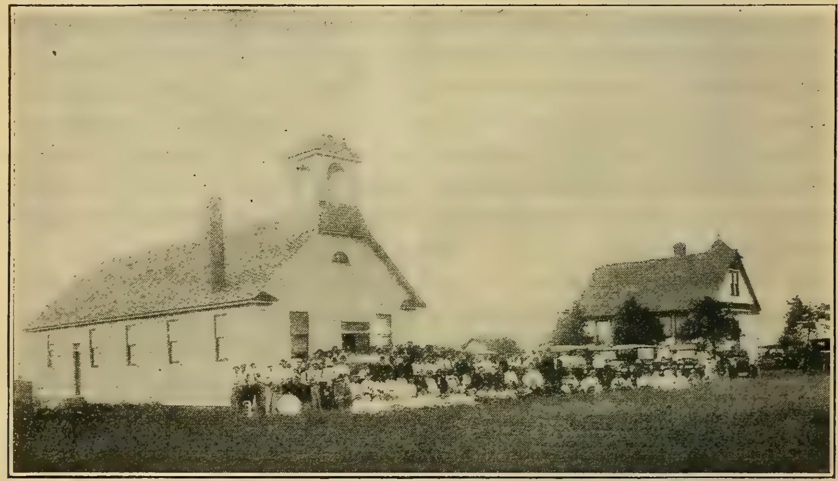

FIG. 9.—Red River Farmers' Club hall, Kittson County, Minn.

The Red River Farmers' Club, in Red River Township, was organized in 1914. Located in a purely agricultural community, its members are entirely farmer families. Nearly every man and woman in the community is an active contributing member. The club met for a while in a schoolhouse, but as the spirit of cooperation grew the desire for a more adequate meeting place increased. A special meeting to consider the possibilities of a community hall was held in the fall of 1916. Committees on plans, finances, etc., were then appointed, and the work began.

The club house aims to provide not only a place where the farmers' club may initiate propaganda for better farms, schools, and homes, but, as a member expressed it, "a real little country theater, one in which plain, common, everyday farm folks may display their musical and dramatic talents."

The cost of the building was $2,000 and of the equipment $500, making a total of $2,500.

The hall is a one-story wooden structure, 28 by 60 feet, with a stage 12 by 20 feet, and a rest room and a kitchen at the other end of the building. Both interior and exterior are painted in pleasing colors, and there are front and side doors. Theater chairs are used for seating, and the floors are of hard wood. There is a piano in the building. The hall is lighted by gas lamps.

Funds for the construction of the building were obtained as follows:

Funds in the club treasury	$175
Receipts from voluntary contributions	1,050
Receipts from picnics	420
Receipts from socials	205
Value of labor contributed	650
Total	2,500

The principal items of maintenance are for light and heat. These are being met by membership fees, monthly luncheons, socials, picnics, and amateur theatricals. As considerable money for the building fund was raised by these methods, it is felt that the maintenance problem is solved.

The title to the building is vested in the farmers' club, which includes in its membership practically every family in the community. The club annually elects five directors, who control and manage the hall.

While the hall has been in existence but a short time, the frequency of its use and the large numbers which avail themselves of its privileges attest its value. Club meetings, with programs, are held twice a month. At alternate meetings pay luncheons are served. Frequent picnics are given at which refreshments or luncheons are sold. Socials and entertainments of various kinds are featured, not the least interesting being the plays managed, staged, and acted by the people of the neighborhood in "the little country theater."

The farmers, through the club, are enabled to cooperate in buying certain supplies and in selling certain farm products, and to make other advantageous business arrangements.

In general, the primary advantage which this building has brought to the community is that it has furnished an adequate and convenient place, specific in purpose, where all, through ownership, feel freedom of use, and where the social and civic ideals of the community can find expression. In addition it has made possible the centering of the interests of the community in a club which, as a compact medium of expression and authority, has tended to unite rural and urban interests.

TAMALPAIS CENTRE BUILDING, KENTFIELD, CALIF.

At the foot of beautiful Mount Tamalpais, in the town of Kentfield, one of a group of small rural communities in Marin County, the Tamalpais Centre Building was made possible in 1909 through gifts of money from one or two progressive citizens.

The trustees stated its aim as follows: "It must be a center of neighborliness wherein all of us, working together, may more fully enjoy the life granted each of us. It is destined to mean opportunity for rest, recreation, and instruction to men, women, and children."

The particular purposes of the building were stated to be: (1) A meeting place for various clubs; (2) a home for the women's organizations; (3) a general meeting place for entertainments, lectures, etc.; (4) a playground for the children; (5) an athletic field for men and boys; (6) a place for classes in gymnastics and dancing for girls and boys; (7) a place where suppers and banquets might be served.

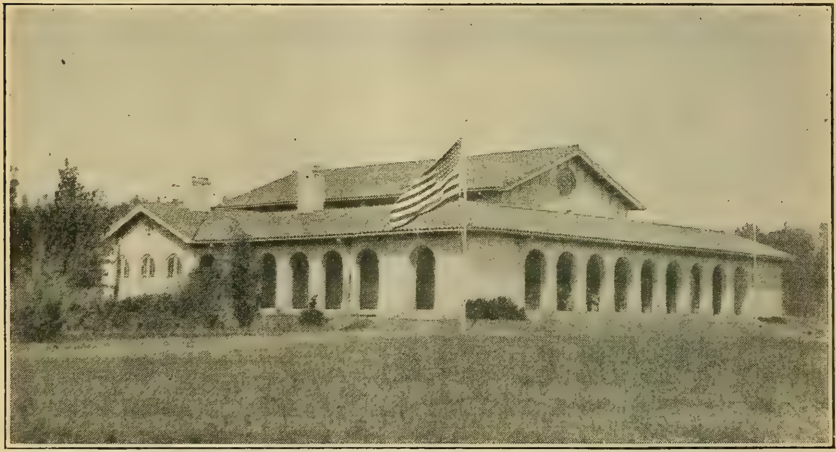

FIG. 10.—Tamalpais center building, Kentfield, Calif.

The cost of the building and equipment, exclusive of the site, was as follows:

Building, including light, heat, and water	$25,000
Furnishings	1,850
Playground equipment	1,000
Draining and filling in of site	10,000
Total	37,850

The building and grounds occupy a beautiful site of 29 acres among the wooded foothills of Mount Tamalpais. The grounds have been drained and graded and laid out for various athletic and outdoor activities. There are a half-mile race track, baseball and basket-ball grounds, tennis courts, and a running track.

The building, of stone and concrete, is of the mission style of architecture, 100 feet square. Around three sides is an arcade 12 feet wide, beautifully arched. The building contains the following rooms:

1. An auditorium 45 by 50 feet, comprising two wings, with movable doors. This contains 400 movable opera chairs and a piano. At the front is a stage 18 by 30 feet, with two sets of scenery, 8 flies, moving-picture curtain, one front and one rear curtain, with 24 electric lights above and 48 footlights.
2. A kitchen 14 by 24 feet, containing coal and gas ranges, four cupboards, and kitchen and table equipment sufficient to feed 130 people at one time.
3. A women's dressing room, with fireplace and couch.
4. A men's dressing room.
5. Four toilets.
6. An office 12 by 13 feet, containing a stove, tables, desks, 90 feet of bookshelves with encyclopedias, historical works, etc., and a safe.
7. A balcony in the rear of the auditorium seats 30 people and contains a moving-picture booth with a picture machine, the property of the public schools. In the arcades are 30 rustic chairs.

The site of 29 acres and the building, including light, heat, and water installations and furnishings to the value of $1,000, were presented to the public by a local resident. Her son furnished funds for the ground reclamation. Another woman, a resident, furnished the playground apparatus. The local woman's club gave furniture to the value of $850.

The following are the expenses from April 1, 1916, to April 1, 1917:

Gas	$8.70
Electricity	42.35
Telephone	55.57
Repairs	23.70
Wood and coal	60.00
Insurance	145.16
Taxes	72.97
Salary of playground teacher	900.00
Salary of one janitor	900.00
Total current expenses	2,208.45
Permanent improvements	97.75
Total	2,306.20

The woman's club pays all expenses except the salaries of the playground teacher and the janitor, which are paid by the donor of the building, and receives all income. In one recent year it raised $1,600 and expended it all on maintenance and upkeep of grounds. It raises money from entertainments, an annual May fête, harvest dances, dues, and rentals.

The building and grounds are owned by a legal corporation called the Tamalpais Centre, organized primarily for the purpose of holding title to certain property, and secondarily, to supervise the improvement and use of the property and the construction of new buildings.

There are 21 members of the corporation, with no set limit to their term of office, and vacancies are filled by vote of the remaining members. This corporation, or board of trustees, elects seven directors from among its number, who have the management of the building. One of the directors, called the dean, was the active manager up to 1911, when the woman's club took charge, at the invitation of the trustees.

Among the organizations using the building at various times are the following:

1. The woman's club. This organization is responsible for such community undertakings as Wild Flower Day, Old Settler's Day, and May Day, held annually, besides the usual club activities. It has for some time had a membership of over 200.

2. The Friendly Circle. This is a club of working men and women having 60 members. Its program usually includes games, reading, reciting, singing, and dancing. Attached to the circle is a civil government class for workingmen who are looking forward to American citizenship.

3. The literary class. This class has studied the Book of Job, Shakespeare, Stephen Phillips, Edmund Rostand, and others.

4. The playground association. This is composed of teachers of the public schools. They meet every Wednesday for a practical course in playground work and then carry the idea of supervised play into their own school yards. Eight schools send teams to the annual May Day contest. The children's playground work at the Centre has been under the trained leadership of a young woman, who, besides the regular outdoor work, has three children's and two women's gymnasium classes under her charge. Connected with this department, under adequate supervision, are the boys' baseball and basket-ball teams.

5. The driving association. This maintains a half-mile track for the speeding of horses, which is open on all days except Sunday. No betting is allowed.

6. The neighborhood Sunday school. The instruction is nonsectarian. At Christmas a manger service is held, at which the young people from the surrounding villages bring presents for the Catholic and Presbyterian orphanages of the county.

7. The stadium committee. This arranges and has charge of the athletic games, meets, etc.

8. The women's gymnasium.

9. The Knights of King Arthur.

10. The art class.

There have also been sewing classes, dancing classes, civil government classes for women, a story hour for children, and a series of "pleasant Sunday afternoons."

The building has been used by the high school for class dances and by the Catholic and Episcopal churches for fairs.

The largest gathering is the annual May fête. At one of these celebrations there were 6,000 present and more than 100 track, field, and platform events were participated in by the boys and girls of the county.

Other events staged at the Centre are: Folk dances, military drills, dramatic entertainments, tennis games and meets, harvest festivals, Arbor Day celebrations, banquets, children's Christmas parties, and meetings of the queens of aviation, the community choral association, and the civic association.

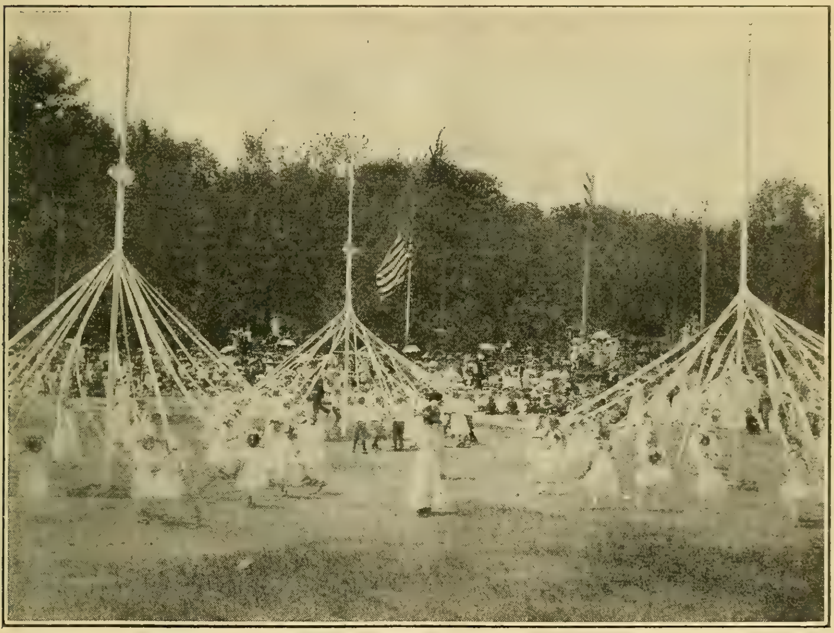

FIG. 11.—Tamalpais Centre, Kentfield, Calif., Maypole dance.

In 1918 a dehydration plant was presented to the Centre, and extensive work was carried on along the line of community drying and conserving of fruit.

AMUSEMENT HALL, WARE SHOALS, S. C.

A recent development in modern industrial relations is the increasing number of business concerns making contributions for social-center buildings for the community, with special rooms and facilities arranged for the recreation of their employees.

Ware Shoals is a town of 2,000 inhabitants, nearly all of whom are connected in some way with the local cotton mill. The corporation owns all the land on which the town is situated. Certain local officials, such as magistrates and constables, are paid jointly by the company and the county.

The main purpose of the building, as stated by the mill company, was to provide a place of recreation and amusement for their employees, as it was felt that if there was a building in which could be centered the educational, physical, and moral forces of the community they would be able to secure and keep a better class of help. A secondary purpose was the provision of a specific and adequate place which would serve as a center for the educational work carried on among the employees at night. At the same time the building would serve as a social center for various local organizations of the town.

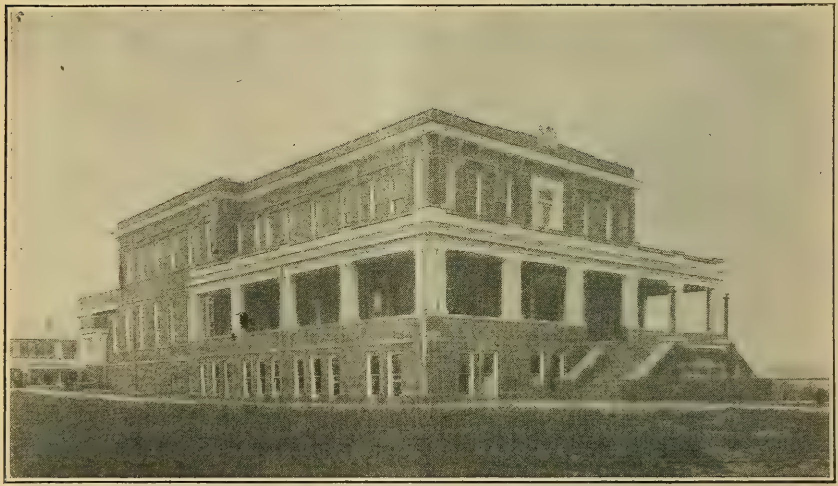

FIG. 12.—Amusement hall, Ware Shoals, S. C.

An association was formed, open to all men and boys of the town, upon payment of stated dues, whether employees of the mill or not.

A recreation building of the most modern type was financed by the company in 1912 at a cost of $35,000. Furnishings which cost $5,000 were provided by the company and the association.

The building is run by the association. The corporation brought about the organization of the association, which, to all intents and purposes, is self-governing, though in the final analysis, ultimate control rests with the corporation. The association is managed by a board of nine directors, first elected by a mass meeting of citizens. Vacancies occurring thereafter are filled by the vote of the board itself. The actual supervision of the building is by the general secretary. The board meets monthly to receive the secretary's report, make recommendations, etc.

The personnel of the building includes a general secretary, a physical director and two assistants, a moving-picture operator, and a janitor. The corporation pays the salary of the general secretary. The heat, light, water, and sewage systems are a part of the general system maintained by the corporation. About $55 per month would cover the expense pertaining to the building incurred by the corporation for this purpose. A few other light expenses are met by the corporation. The annual budget of the association is about $6,000, including (a) salaries; those of the physical director and the first and second assistants are fixed and total $2,200 per year; the moving-picture operator is paid per evening, and (b) general expenses, which include support for town religious and welfare work, for various scholarships, for local athletic teams, and for certain State, religious, and welfare work.

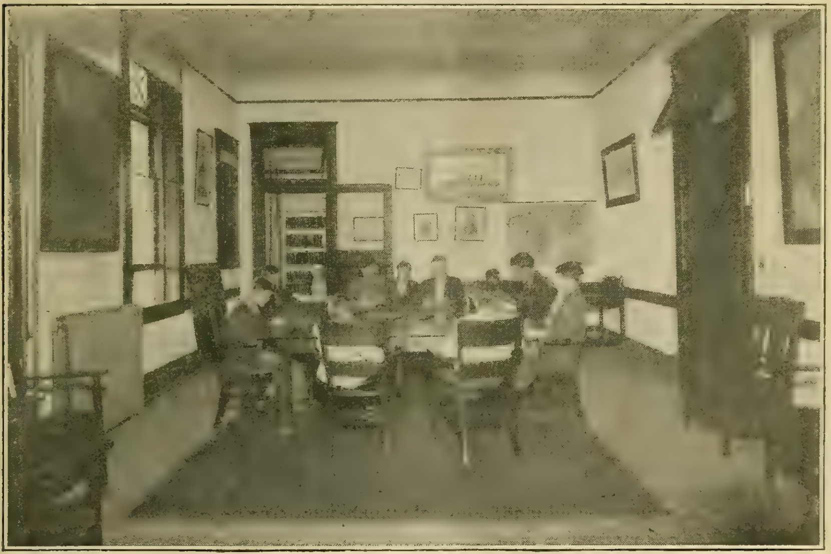

FIG. 13.—Amusement hall, Ware Shoals, S. C., reading room.

The association budget expenses are covered by membership fees, moving-picture receipts, billiard and bowling receipts, towel rentals, fees for admission to athletic games, receipts from home-talent plays, and some donations. Association dues are fixed at $3 per annum for men and $1.50 per annum for boys.

The building is of two stories with basement, and the dimensions are 60 by 150 feet. The upper story contains a women's rest room, a kitchen, a pantry, a banquet hall, a lodge room, lodge paraphernalia rooms, and two toilets. The lower story contains the secretary's office, a writing room, a reading room, two billiard rooms, an auditorium with stage, two dressing rooms, a moving-picture room, and three toilets. The basement contains two bowling alleys, a boys' game room, a well-equipped gymnasium, a locker room with 128 lockers, a multiple-bath room, various toilets, and a boiler room.

While the building is primarily for men and boys, there is a regular place in the gymnasium schedule for the women's classes and also a weekly "ladies' night." Various organizations of women and girls, such as the Camp Fire Girls and the tomato club, use the building regularly. Both men and women take part in all the social activities, such as entertainments, plays, lyceums, spelling bees, moving pictures, and banquets, as well as the religious work. The women of the town and country have exclusive use of the rest room, while the school children have the use of the gymnasium, under the physical director one afternoon each week.

Included in the equipment of the building is a moving-picture machine, which is used weekly for entertainments. The association secures its films, mainly of an educational nature, from various private exchanges.

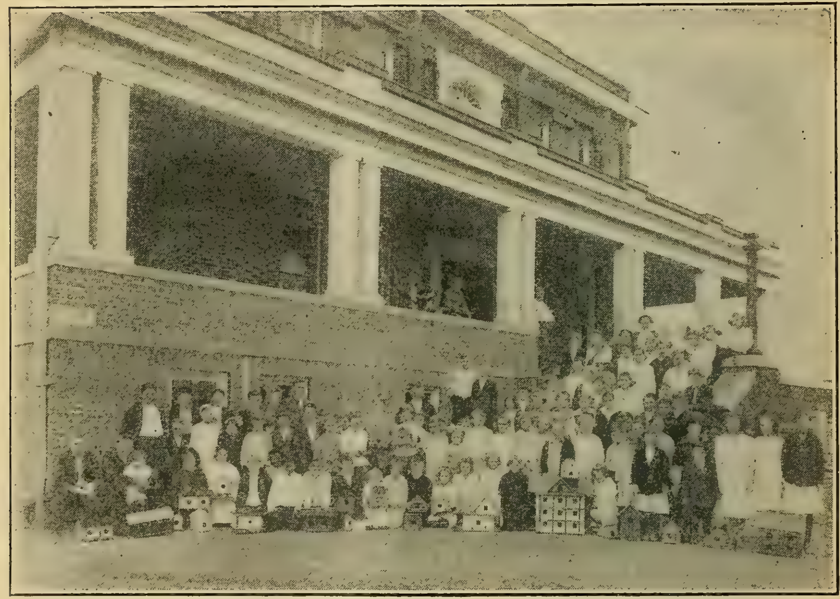

FIG. 14.—Amusement hall, Ware Shoals, S. C., the Audubon Bird Club.

Outdoor athletics are emphasized, such as baseball, basket ball, volley ball, tennis, and playground activities.

Night-school work is for all, whether members of the association or not. There are four teachers, and the work is partly supported by the State and partly by the mill company.

Three fraternal lodges meet in the building and have special paraphernalia rooms, which were included for this purpose in the original plans of the building.

DIXON TOWNSHIP BUILDING, ARGONIA, KANS.

The Dixon Township Building of Argonia, Kans., is worthy of note as being an attempt to unite the interests and aspirations of the farming communities with those of the trading center, with the township as a unit, through a common building designed to serve for large public gatherings, such as farmers' institutes, union church services, high-school entertainments, and for township offices.

The financing of a township building was recently made practicable by a special act of the Kansas State Legislature permitting townships to vote bonds for the construction of such buildings to the amount of $5,000.[1]

The library association, the farmers' institute, and the schools had formerly worked for a social-center building, but without success. In compliance with the provisions of the new law a petition was placed before the township board, signed by 25 per cent of the voters, requesting that the bond question be submitted to vote. As a result, a building was erected in 1916 by the township board, at a cost of $6,809, including $1,809 from general funds.

The total cost may be itemized as follows:

Land		$500
Building:		
Materials	$2,589	
Labor	1,920	
		4,509
Furnishings		1,800
Total outlay		6,809

The chief maintenance expenses are those connected with light, heat, and repairs. There is no regular janitor, and the building is cared for largely by the organizations using it. Expenses are met chiefly by rentals, which are $3 per night for each entertainment.

The building is 50 by 90 feet and is made of brick, with a cement foundation, and with metal ceilings and plastered walls inside.

The largest room is the auditorium with 600 chairs on a floor which has an incline of about 1 inch to the foot. It is furnished with a piano and is lighted by six 150-candlepower lamps and four 100-candlepower lamps.

At the front of the auditorium is a stage 20 by 24 feet, with an opening 12 feet high. The stage has five drop curtains, six wing curtains, and a curtain for moving pictures. At either side of the stage is a dressing room 8 by 10 feet. At the rear of the auditorium is a gallery 12 by 48 feet, seating 175 people. Underneath the gallery are the library room and the township officials' room, separated by an entrance hall leading from the front door to the auditorium.

The library is 15 by 17 feet and is furnished with chairs, writing desks, and magazine tables, and with bookcases containing 600 volumes.

The officials' room is 15 by 20 feet and contains office furniture, the township records, a safe, a stove, and a telephone. In this room also is a ticket window, from which tickets to the various entertainments are sold.

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[1] See Laws (State of Kansas), chapter 118, section 9560, as amended by chapter 332, Laws of 1911.

The main floor is of wood, but between the front row of opera chairs and the stage is a strip of cement floor 15 feet wide and extending across the building. At either end of this strip is a large double door through which farm stock is brought onto the cement floor, there to be judged at stock shows or fairs, before the public. The basement contains two rooms with cement floors, each 20 by 50 feet, and a furnace room, 12 by 14 feet. The building has running water and is heated by hot air.

The building was planned by the township board in consultation with the local builder. Labor was hired by the day and material bought direct from the retailer. It is in general charge of the board and directly managed by the township trustee, who maintains an office in the building.

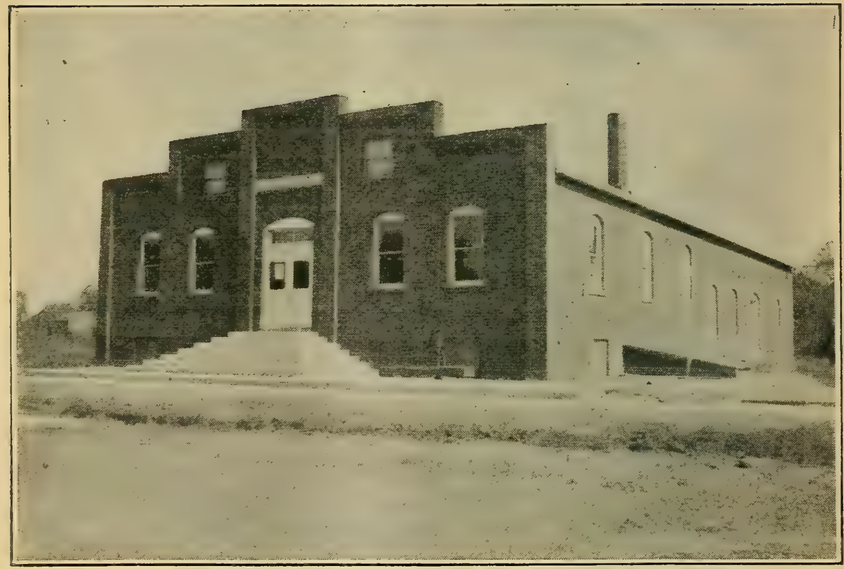

FIG. 15.—Dixon Township building, Argonia, Kans.

Among the activities for which it has been used are: Union revival meetings, lyceum course, community lecture course given by the State college of agriculture, community Christmas program, pageants, high school plays, glee-club entertainments, farmers' short course given by the State college of agriculture, farmers' institute, and fairs and stock shows. It is the regular meeting place of the Farmers' Union, the commercial club, the library board, the township board, and various other township and village organizations. It serves a population of 950 people, about equally divided between the village and the surrounding farms.

REMBRANT COMMUNITY BUILDING, WOODSTOCK, TENN.

Communities which are organized for social and civic betterment often realize that a community building would greatly facilitate their work, but feel that since they can not command extensive funds they can not have such a building. While it is true that a commodious building with various rooms for different purposes, provided with convenient furniture and different lines of useful equipment, is a great aid to a community organization, it is surprising how much can be accomplished in the way of a building with slight financial resources.

Two problems faced the people of Woodstock, living in the open country, far from town or railway, in Shelby County, Tenn. They were animated by a strong desire for the betterment of community life. A cooperative club had been formed, but there was no adequate meeting place, no building whose arrangement would lend itself to the successful carrying out of their plans. Moreover, these farming people could not command funds sufficient for the erection of such a building.

The second problem was what to do with their two-room schoolhouse, abandoned through consolidation, the pupils being transported several miles now to the new building. The schoolhouse, old and dilapidated, had been used as a gypsy camp, and the school authorities had offered it for sale for $200.

Both problems were soon solved by the decision of the club to secure control of the old building, and to reconstruct and equip it as their social center home.

The club had fixed as its purpose "the betterment of community life from the social, educational, and economic standpoint," and had planned an ambitious but practical program for its accomplishment. It had enrolled practically every person in the neighborhood over 16 years of age, elected the usual officers, together with a board of six directors, who were given charge of the carrying out of the building plans, and appointed committees on sanitation, education, civic beautification, and recreation.

After the proper guaranty of its future use for civic welfare, the county school officials were induced to give an indefinite lease of the grounds and building to the cooperative club, the county retaining title. Then began a fine example of community cooperation in public work. The grounds, 2 acres in extent, were put in condition and the building reconstructed, entirely through voluntary effort. Some gave lumber, some labor, some material, and some equipment. All took part. While the men were working on the building the women were preparing and serving lunches.

The club realized the value of a pleasant approach and beautiful setting for their home. Approaching roads were laid out, the grounds were leveled and drained, trees, both useful and ornamental, were planted, weeds were destroyed, and gravel walks were made, leading in various directions. At the front of the house beds of fragrant flowers were planted.

As an aid to their future club work in experimental agriculture, the vacant space in the rear was planted to vegetables and berries. In connection with this a well was dug and a pump installed.

The building was neatly painted without and within, rugs, shades, and curtains placed, floors waxed, and the walls hung with appropriate pictures. A stage was provided for entertainments and local plays.

The furniture installed included a number of easy chairs, 24 folding chairs, a library table, bookcases, a heating stove, an oil stove, 4 dining tables, a kitchen cabinet, china and glassware, cutlery, and kitchen utensils.

No direct money contributions were solicited. Entertainments, suppers, sales, and ice-cream socials provided considerable cash. Much furniture was donated. A "parcel-post sale" provided sufficient funds to purchase a phonograph. A "good-book week" resulted in various contributions to the library. A "china shower" furnished the necessary dishes.

The building is of cottage form, one story high, and is provided with an entrance hall, 8 by 20 feet, used also as a library and reading room; an assembly hall 21 by 40 feet, with stage; and a dining room and kitchen of the same size.

The plant is valued at $2,200 and is a signal monument to community spirit and practical neighborhood cooperation, and a fine example of what may be accomplished in a rural community of limited financial resources.

On July 4, 1916, a happy and contented neighborhood gathered in the building to dedicate the fruits of their united labors with an appropriate "sunset celebration," since which time the building has been in almost continuous use.

Not only was the building reconstructed and equipped without financial contributions, but it is maintained and the work carried on in it by a club without dues or membership fees. Wood, coal, janitor service, and repairs are voluntarily contributed or provided for by receipts from entertainments.

Besides the ordinary social activities are included agricultural meetings, canning and cooking demonstrations, sewing, classes in rug and basket weaving, floral exhibits, book and magazine exchanges, waste-paper sales, quilting parties, garden contests, community, county, and tri-State fair exhibits, barbecues, community singing, and the celebration of national holidays.

If the value to the neighborhood of a community building is to be estimated by the uses to which it is put and the needs which it satisfies, then this study would indicate that the community building as a general rule must be accorded a high place. Not all communities which own them are awake as yet to their potential possibilities, but there are enough examples of efficient use combined with far-reaching plans to warrant the conclusion that they will prove to be effective instruments in the improvement of rural social conditions.

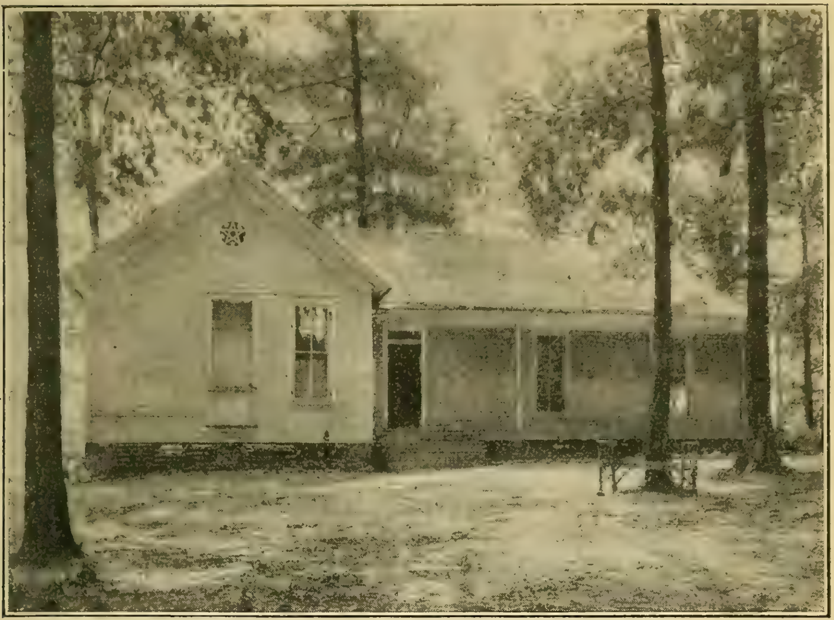

FIG. 16.—Rembrant community building, Woodstock, Tenn.

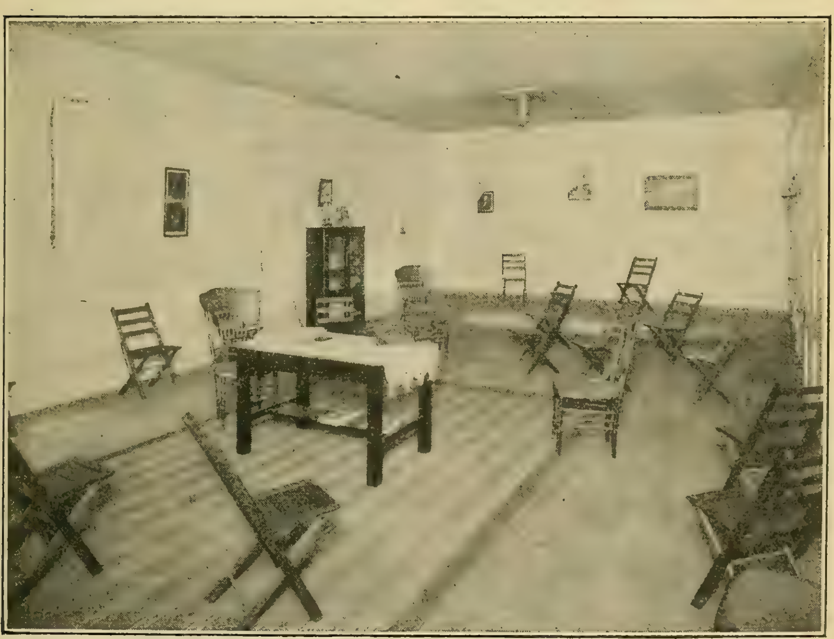

FIG. 17.—Rembrant community building, Woodstock, Tenn., parlor (used also as assembly hall).

COMMUNITY BUILDINGS STUDIED, CLASSIFIED ACCORDING TO POPULATION OF PLACE IN WHICH LOCATED.

Population.	Number of buildings.
Open country	83
Less than 500	58
500 to 1,000	21
1,000 to 1,500	14
1,500 to 2,000	14
2,000 to 2,500	11
2,500 to 3,000	5
3,000 to 4,000	9
4,000 to 5,000	3
5,000 to 6,000	3
6,000 to 7,000	3
7,000 to 8,000	7
8,000 to 9,000	3
10,000 to 15,000	12
15,000 to 20,000	4
20,000 to 25,000	3
25,000 to 30,000	2
More than 30,000	1
Total	256

A LIST OF COMMUNITY BUILDINGS SELECTED FROM THOSE VISITED OR STUDIED THROUGH CORRESPONDENCE.

Arizona:
- Madison.—P. O., Phoenix. Improvement Club Building.
- Roosevelt District.—P. O., Phoenix. Neighborhood House.
- Somerton.—Woman's Club and Community Building.
- Snowflake.—Social Hall.

Arkansas:
- Scott.—Union Ladies' Aid Society and Community Building.

California:
- Blue Lake.—Civic Center.
- Bogue.—P. O., Yuba City. Bogue Hall.
- Kentfield.—Tamalpais Centre Building.
- La Jolla.
- Mt. George.—P. O., Napa. Farm Center Building.
- Santa Barbara.—Recreation Building.

Connecticut:
- Bethel.—Church House.
- Bolton.—Bolton Hall.
- Bushby Hill. — P. O., Simsbury. Neighborhood House.
- Gilead.—P. O., Andover. Gilead Hall.
- Glastonbury. — Williams Memorial Building.
- Weatogue.—Neighborhood House.

Delaware:
- Henry Clay Factory.—Hagley Community House.

Florida:
- Goulds.

Idaho:
- Potlatch.—Community Gymnasium.

Illinois:
- Brimfield.
- Kenilworth.—Assembly Hall.
- McLean.
- Oregon.
- Palos Park.—Improvement Club Building.
- River Forest. — P. O., Oak Park. Woman's Club and Community Building.
- Winnetka.—Community House.

Indiana:
- Advance.
- Darlington.
- La Porte.—Women's Building.
- New Market.
- Seymour.—Farmers' Club Building.

Iowa:
- Dexter.
- Lincoln Township.—P. O. Clinton. Ladies' Mutual Benefit Association Building.
- Logan.—Agricultural Extension Association Building.
- Pocahontas.—Lincoln Parish Hall.
- Stuart.

Kansas:
- Argonia.—Dixon Township Building.
- Asherville.—Community Hall.
- Coldwater.
- Gardner.—Westminister Hall.
- Geneva.—Community Hall.
- *Junction City.
- *Leavenworth.
- *Manhattan.
- Mankato.—Y. M. C. A. and Community Building.
- Marysville.
- Potwin.
- Russell.—Community Hall.

Louisiana:
- Bogalusa.—Y. M. C. A. and Community Building.
- Longacre.—P. O. De Ridder.

Maine:
- Exeter Mills.—P. O., Exeter. Exeter Mills Hall.
- Glen Cove.—P. O., Rockport. Social Center Building.
- Seal Harbor.—Neighborhood Hall.
- Steuben.—Parish House and Library.

Massachusetts:
- Belchertown.
- Greendale.—P. O., Worcester. Improvement Society Hall.
- Holden.—Holden Community House.
- Millington.—Moore Hall.
- Milton.—Cunningham Gymnasium and Recreation Park.

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* Owned locally and operated by the National War Camp Community Service.

Massachusetts—Continued.
Montague City.—Library Hall.
Norwood.—Norwood Civic Association Club House.
Peabody.—Community House.
Pelham.—P. O., Amherst. Neighborhood Hall.
Scituate.—Allen Memorial Library.
South Ashburnham.—Club House.
Three Rivers.—Pickering Hall.
Michigan:
*Camp Custer.—P. O., Battle Creek. Roosevelt Community Building.
Centerville.—Community Play House.
Midland.
Reed City.
St. Helen.—Township Hall.
Scottville.—Community Hall.
Sand Lake.—Sand Lake Auditorium.
Minnesota:
East Castle Rock.—P. O., Castle Rock. East Castle Rock Country Club Hall.
Eden Township.—P. O., Pipestone. Harmony Hall.
Eveleth.—Recreation Building.
Hendrum.—Hendrum Auditorium.
Ironton.—Village Hall.
Minnewashta.—P. O., St. Bonifacius. Minnewashta Improvement Club Hall.
Northfield.
Red River Township.—P. O., Hallock. Community Hall.
St. Cloud.—St. Cloud Institute.
Sleepy Eye.—R. F. D., Jolly Boosters' Club House.
Stately Township.—P. O., Comfrey. Farmers' Club Building.
Sveadahl.—Luther Hall.
Tamarack.—Farmers' Club Hall.
Wheaton.
Mississippi;
Tupelo.—Cotton Mills Club Building.
Missouri:
Ashland.—Church Community Building.
Union Hall District.—P. O., Atlanta.
Fenton.—Farmers' Club Building.
Lee's Summit.—The B. O. Club Building.
Montana:
Fairfield.—Community Hall.
Little Jewel.—Club Building.
Menard.—Community Hall.
Orchard Homes.—P. O., Missoula. Orchard Homes Country Life Club Building.
Plentywood.—Progressive Farmers' Club Hall.
Sioux Pass.—Sioux Pass Hall.
Wibaux.—Community House.
Willard.—Willard Hall.
Nebraska:
Elgin.
New Hampshire:
Dover.—Lothrop Memorial Hall.
Lebanon.
Meredith Neck.—P. O., Meredith. Meredith Neck Farmers' Association Club House.
Swanzey.—Community House.
New Jersey:
Bogota.—Community House.
Oceanic.—Parish House and Community Building.
New Mexico:
Albuquerque.—Commercial Club Building.
New York:
Chateaugay.—Town Hall.
Chatham.—Morris Memorial Building.
Endicott.—Ideal Home.
Glen Cove.—Neighborhood House.
Hoosick Falls.—Neighborhood House.
Johnson City.—"Your Home"-Johnson City Library.
Lawyersville.—Community House.
Loudonville.—Loudon Hall.
Locust Valley.—Matinecock Neighborhood House.
Milton.
Newark.—Newark Gymnasium.
Owego.—Social Center Building.
Pawling.—Aiken Hall.
Philmont.—Crusader Hall.
Pleasant Valley.—Pleasant Valley Free Library and Community Building.
Rhinecliff.—Memorial Building.
Riverside.—P. O., New York. War Camp Community Service Building.
Roslyn.—Neighborhood House.
Wesley Chapel Center.—P. O., Suffern, Community Club House.
Westbury.—Westbury Parish Hall.
North Carolina:
Albemarle.—Community House.
Mocksville.
Salisbury.
North Dakota:
Kensal, R. F. D.—McKinley Farmers' Association Hall.
Ohio:
Kinsman.—Library and Community Building.
Lebanon.—Harmon Hall.
Mad River Township—P. O., Dayton. Improvement Association Building.
Oklahoma:
Sooner.—P. O., Oklahoma City. Union Church and Community Building.
Oregon:
Garfield.—P. O., Estacada. Country Club.
George.—P. O., Estacada. Social and Commercial Club Building.
Plymouth.—P. O., Corvallis. Church Community Building.

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* Owned locally and operated by the National War Camp Community Service.

Pennsylvania:
- Butler.
- Huntingdon.
- McClellandtown.—Christian Brotherhood Building.
- Newfoundland.
- Washington.

Rhode Island:
- Cumberland.—P. O., Ashton. Parish House.

South Carolina:
- Saxon Mills.—P. O., Spartanburg.
- Ware Shoals.—Recreation Building.

South Dakota:
- Byron.—P. O., Pierre. Byron Club House.

Tennessee:
- Cuba.—P. O., Kerrville. West Union Community Building.
- Woodstock.—P. O., Memphis. Rembrant Community Building.

Texas:
- Bay View—P. O., Palacios. Bay View Community House.
- Danevang.—Danevang Meeting House.
- Groesbeck.—American League Chapter House.

Utah:
- Hyrum.—Social Hall.
- Timpanogas.—P. O., Provo. Amusement Hall.

Vermont:
- Proctor.—Proctor Free Library.
- Randolph.—Chandler Music Hall.
- Rutland.—Community House.
- St. Albans.—Stannard Memorial Building.
- Wilder.—Library and Community Building.

Virginia:
- Carrollton.—Community Hall.
- Carrsville.—Carrsville Hall.
- Long Dale, R. F. D.—Long Dale Union Chapel.

Washington:
- Bethany.—P. O., Sunnyside. Community Hall.
- Snoqualmie.—Gymnasium.

Wisconsin:
- Bloomfield.—P. O., Lake Geneva. Bloomfield Township Hall.
- Brush Creek.—P. O., Ontario. Brush Creek Temperance Hall.
- Burke.—P. O., Madison. Township Hall.
- Como.—P. O., Lake Geneva. Geneva Township Hall.
- Fairfield Township.—P. O. Baraboo. Fairfield Township Hall.
- Green Bay.—Woman's Building.
- Honey Creek.—People's Hall.
- Mineral Point.—Municipal Building.
- Nashotah.—Men's Club Hall.
- Oconto.—Community House.
- Pigeon Creek.—P. O., Pigeon Falls. Lutheran Young People's Society Hall.
- Richland Center.—Richland Center Municipal Building.
- St. Croix Falls.—Municipal Building.
- Sheboygan.—James H. Mead Club Building.
- Spring Valley.—Village Hall.
- Zenda.—Linn Township Hall.

Wyoming:
- Powell, R. F. D.—North End Community Building.

NOTE.—Buildings not particularly identified are commonly known as "the community building."

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GEORGE LIVINGSTON, Acting Chief

Washington, D. C. PROFESSIONAL PAPER December 15, 1919

CONSTRUCTION AND FIRE PROTECTION OF COTTON WAREHOUSES

By

J. M. WORKMAN

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 802
Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

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QUALITY AND VALUE OF IMPORTANT TYPES OF PEAT MATERIAL

A CLASSIFICATION OF PEAT BASED UPON ITS BOTANICAL COMPOSITION AND PHYSICAL AND CHEMICAL CHARACTERISTICS

By

ALFRED P. DACHNOWSKI, Physiologist
Soil-Fertility Investigations

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TWO LEAFHOPPERS INJURIOUS TO APPLE NURSERY STOCK

By

A. J. ACKERMAN, Scientific Assistant
Deciduous Fruit Insect Investigations

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Joint Contribution from the Bureau of Plant Industry, WM. A. TAYLOR, Chief
and the Bureau of Crop Estimates, L. M. ESTABROOK, Chief

Washington, D. C. December 8, 1919

PEACHES: PRODUCTION ESTIMATES AND IMPORTANT COMMERCIAL DISTRICTS AND VARIETIES

By
H. P. GOULD, Bureau of Plant Industry, and
FRANK ANDREWS, Bureau of Crop Estimates

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Contribution from the Bureau of Entomology
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AMERICAN FOULBROOD

By

G. F. WHITE
Specialist in Insect Diseases

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UNITED STATES DEPARTMENT OF AGRICULTURE

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Contribution from the Bureau of Entomology
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By

G. F. WHITE, Specialist in Insect Diseases

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A SYSTEM OF BOOKKEEPING FOR GRAIN ELEVATORS

By

B. B. MASON, Assistant in Market Business Practice, FRANK ROBOTKA
Field Agent in Market Business Practice, cooperating with the College of
Agriculture of the University of Minnesota, and A. V. SWARTHOUT
Investigator in Market Business Practice

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 813
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WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER June 25, 1920

CITRUS-FRUIT IMPROVEMENT
A STUDY OF BUD VARIATION IN THE EUREKA LEMON

By

A. D. SHAMEL, Physiologist, L. B. SCOTT, Pomologist, C. S. POMEROY, Assistant Pomologist, and C. L. DYER, Scientific Assistant, Fruit-Improvement Investigations, Office of Horticultural and Pomological Investigations

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THE STANDARD DAY'S WORK IN CENTRAL ILLINOIS

PERFORMANCE OF IMPLEMENTS AND CREWS AS INDICATED BY REPORTS FROM 600 FARMS IN A TYPICAL CORN-BELT AREA

By

H. R. TOLLEY, Scientific Assistant, and
L. M. CHURCH, Assistant in Farm Accounting

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WM. A. TAYLOR, Chief

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CITRUS-FRUIT IMPROVEMENT
A STUDY OF BUD VARIATION IN THE LISBON LEMON

By

A. D. SHAMEL, Physiologist, L. B. SCOTT, Pomologist, C. S. POMEROY, Assistant Pomologist, and C. L. DYER, Scientific Assistant, Fruit-Improvement Investigations, Office of Horticultural and Pomological Investigations

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WM. A. TAYLOR, Chief

Washington, D. C. ▼ January 19, 1920

STREET TREES

By

F. L. MULFORD, Horticulturist

Office of Horticultural and
Pomological Investigations

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JOHN R. MOHLER, Chief

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OBSERVATIONS ON THE LIFE HISTORY OF ASCARIS LUMBRICOIDES

By

B. H. RANSOM, Chief, and W. D. FOSTER,
Junior Zoologist, Zoological Division

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JACK PINE

By

WILLIAM DENT STERRETT, Forest Examiner

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FROST PROTECTION IN LEMON ORCHARDS

By

A. D. SHAMEL, Physiologist, L. B. SCOTT, Pomologist, and C. S. POMEROY, Assistant Pomologist, Office of Horticultural and Pomological Investigations

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EXPERIMENTS WITH KHERSON AND SIXTY-DAY OATS

By

C. W. WARBURTON, Agronomist in Charge, and T. R. STANTON
Assistant Agronomist in Oat Investigations
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and the Insecticide and Fungicide Board, J. K. HAYWOOD, Chairman

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INSECT POWDER

By

C. C. McDONNELL, Chief, R. C. ROARK, Assistant Chemist,
Insecticide and Fungicide Laboratory, and G. L. KEENAN,
Microanalyst, Microchemical Laboratory

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